THE

STUDENT'S COMPENDIUM

OF

COMPARATIVE ANATOMY.

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"Sparsa coegi."—OVID.

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TO

PHILIP CRAMPTON, M. D., F. R. S.

SURGEON GENERAL TO THE FORCES IN IRELAND,

&c. &c. &c.

AS AN INADEQUATE, BUT SINCERE TESTIMONY OF RESPECT,

TO

DISTINGUISHED SCIENTIFIC ATTAINMENTS,

AND

DESERVED PROFESSIONAL EMINENCE,

THIS VOLUME

IS INSCRIBED,

BY

HIS GRATEFUL AND OBLIGED FRIEND,

THE AUTHOR.

PREFACE.

In the compilation of these pages no originality is claimed, but the labours of modern authors have been freely appealed to, and it is trusted, on every occasion, with due respect. A list of the several authors consulted has been added at the end of the book.

I have to acknowledge several obligations to my friend Dr. Houston of this city, whose scientific acquirements and connection with the Museum of the College, have well qualified him for the many auxiliary favours he has conferred on me.

P. E.

Dublin, 33 *Aungier Street*,
September, 1838.

COMPENDIUM

OF

COMPARATIVE ANATOMY.

CHAPTER I.

PRELIMINARY OBSERVATIONS.

When we turn our attention to the busy theatre of animal life, we are at once attracted by scenes of wonder and delight. The works of nature appear unbounded in extent, variety, and riches. Wherever the eye is cast, from the icy regions of the pole to the scorching sands of the line, it beholds life displayed in forms as endless as they are enchanting.

Every region and every element is the abode of numerous animals, and is admirably suited to their peculiar living habits and instincts; the vastness of their number may be estimated from the declaration of the celebrated Ehrenberg, that a single cubic line which is less than a drop of fluid contains 500,000,000 monads.

But however varied and delightful the occupations of the zoologist may be, his information is still defective, and he perceives that the interior machinery of life is hidden from his observation, and its springs concealed by clouds which nothing but the light of dissections can dispel.

When once engaged in this captivating department of his investigations, he begins to observe the beautifully progressive development of organisation, varied and modified in obedience to certain laws; he will often behold the same animal, according to the particular epoch of its existence, undergoing metamorphosis, appearing under different characters, and playing very different parts on the stage of life.

Having entered a little more fully into the details of comparative anatomy, he will often observe an organ which has attained a high degree of development, and whose functions are perfectly understood in one animal; diminutive, rudimentary, and apparently useless in another. Hence it must be obvious, that he who aspires to a perfect knowledge of human structure and function, must extend his researches to an examination of the animal kingdom in general; and accordingly great advantage will be found in a previous acquaintance with some one or more of the most approved classifications in natural history.

Every classification hitherto proposed has in some particular or other its imperfections; but it matters little what scale we adopt,

or whether we make use of several, provided that our object of conveying or acquiring a knowledge of the comparative structure of animal bodies be attained. This must be my excuse for appearing in some places to have followed the arrangement of Cuvier, and in others, that of Dr. Grant, both having their excellences, and their authors holding the highest place as authorities on the subject.

Cuvier's and Grant's classifications are therefore subjoined, accompanied by *familiar illustrations* of each, to lead the student at one glance to the objects which each subdivision embraces. The examples appended to Grant's classification have been added by myself, whilst those of Cuvier have been taken from Dr. Houston's Descriptive Catalogue of the Preparations in the Museum of the Royal College of Surgeons in Ireland, with a few additional examples from Roget's Bridgewater Treatise.

It might appear an omission not to make some allusion to the arrangement of the animal kingdom adopted by the immortal Linnæus, but the researches of later zoologists have proved it so defective, that it is not followed by any writer or teacher of the present day, and needs therefore but a cursory allusion. Suffice it to state that he divided the whole animal kingdom into six *classes*, Mammalia, Aves, Reptilia, Pisces, Insecta, Vermes, founding his classification mainly on the peculiarities afforded by the respiratory and sanguineous systems.

OUTLINE OF CUVIER'S CLASSIFICATION OF ANIMALS.

FOUR GREAT DIVISIONS.

1. Vertebrata.
2. Mollusca.
3. Articulata.
4. Radiata.

VERTEBRATA.

Characters.—Internal skeleton—brain and spinal marrow in separate cavities—red blood and muscular heart—mouth with horizontal jaws—five organs of sense—never more than four limbs—separate sexes.

MOLLUSCA.

Ch.—No skeleton—muscles all attached to external skin—nervous system situated in the visceral cavity and composed of separate masses joined by nervous filaments—taste, sight, or as in one instance, hearing, the only senses—organs of circulation, respiration, and digestion very perfect.

ARTICULATA.

Ch.—No skeleton—two long nervous chords with ganglia at intervals—have usually taste and sight—divided in jointed rings, soft or hard, to inside of which muscles attached—sometimes lateral limbs, sometimes none—jaws when present always lateral.

RADIATA.

Ch.—Organs of movement and sense disposed circularly around a centre, not symmetrically as in the preceding—no visible nerves—no organs of sense or circulation—respiration by the outward integument—intestines often a simple bag—sometimes the animal is but a homogeneous pulp without aperture or cavity.

I. VERTEBRATA.

Class 1. MAMMALIA.

Order	1. Bimana - -	*Examples,*	Man.
	2. Quadrumana -	——	Monkey, ape, lemur.
	3. Cheirotera -	——	Bat, colugo.
	4. Insectivora -	——	Hedge-hog, shrew, mole.
	5. Plantigrada -	——	Bear, badger, glutton.
	6. Digitigrada -	——	Dog, lion, cat, marten, weasel, otter.
	7. Amphibia - -	——	Seal, walrus.
	8. Marsupialia -	——	Opossum, kangaroo, wombat.
	9. Edentata - -	——	Sloth, armadillo, ant-eater.
	10. Rodentia - -	——	Beaver, rat, squirrel, porcupine, hare.
	11. Ruminantia -	——	Camel, deer, giraffe, sheep, ox.
	12. Pachydermata	——	Elephant, hog, rhinoceros, tapir, horse.
	13. Cetacea -	——	Dolphin, whale.

Cl. 2. AVES.

Ord.	1. Accipitres	*Exam.*	Vulture, eagle, owl, hawk.
	2. Passeres - -	——	Thrush, swallow, lark, crow, sparrow.
	3. Scansores - -	——	Woodpecker, cuckoo, toucan, parrot.
	4. Gallinæ - -	——	Peacock, pheasant, grouse, pigeon.
	5. Grallæ - -	——	Plover, stork, snipe, ibis, flamingo.
	6. Palmipedes -	——	Auk, grebe, gull, pelican, swan, duck.

Cl. 3. REPTILIA.

Ord.	1. Chelonia -	*Exam.*	Tortoise, turtle, emys.
	2. Sauria - - -	——	Crocodile, lizard, gecko, chameleon.
	3. Ophidia - -	——	Serpents, boa, viper.
	4. Batrachia -	——	Frog, salamander, newt, proteus, siren.

Cl. 4. PISCES.

Ord.	1. Chondropterygii	*Exam.*	Lamprey, shark, ray, sturgeon.
	2. Malacopterygii	——	Salmon, herring, cod, sole, eel.
	3. Lophobranchii	——	Pike-fish, pegasus.
	4. Pleclognathii	——	Sun-fish, trunk-fish.
	5. Acanthopterygii	——	Perch, mackerel, sword-fish.

II. MOLLUSCA.

Head crowned with tentacula which serve as feet.	*Cl.* I. Cephalopoda	*Exam.*	Cuttle-fish, calamary, nautilus.
Progression by fins placed near the head.	2. Pteropoda	——	Clio, hyalœa.
Head free progression on the belly.	3. Gasteropoda	——	Slug, snail, limpet.
Without distinct head.	4. Acephala	——	Oyster, muscle, ascidia.

Two long arms at the mouth for seizing objects.	5. BRACHIOPODA	*Exam.*	Lingula, terebatula.
Arms very numerous, articulated, horny.	6. CIRRHOPODA	———	Barnacle, triton.

III. ARTICULATA.

Cl. 1. ANNELIDA.

Ord.	1. TUBICOLA - - - -	*Exam.*	Serpula, sabella, amphitrite.
	2. DORSIBRANCHIA - -	———	Nereis, aphrodite, lob-worm.
	3. ABRANCHIA - - -	———	Earth-worm, leech, nais, hair-worm.

CL. 2. CRUSTACEA.

Ord.	1. MALACOSTRACA - -	*Exam.*	
	2. DECAPODA - - -	———	Lobster, crab, prawn.
	3. STOMOPODA - - -	———	Squill, phyllosoma.
	4. AMPHIPODA - - -	———	Grammarus, sand-hopper.
	5. LÆMODIPODA - -	———	Cyamus.
	6. ISOPODA - - - -	———	Wood-louse.
	7. ENTOMOSTRATA - -	———	Monoculus.

CL. 3. ARACHNIDA.

Ord.	1. PULMONALIA - - -	*Exam.*	Spider, tarantula, scorpion.
	2. TRACHEALIA - - -	———	Phalangium, mite.

CL. 4. INSECTA.

Ord.	1. APTERA - - - -	*Exam.*	Centipede, podura.
	2. COLEOPTERA - - -	———	Beetle, glow-worm.
	3. ORTHOPTERA - -	———	Grass-hopper, locust.
	4. HEMIPTORA - - -	———	Fire-fly, aphis.
	5. NEUROPTERA - -	———	Dragon-fly, ephemera.
	6. HYMENOPTERA - -	———	Bee, wasp, ant.
	7. LEPIDOPTERA - -	———	Butter-fly, moth.
	8. RHIPIPTERA - - -	———	Xenos, stylops.
	9. DIPTERA - - - -	———	Gnat, house-fly.

IV. RADIATA *vel* ZOOPHYTA.

Class	1. ECHINODERMATA -	*Exam.*	Star-fish, sea-urchin.
	2. ENTOZOA - - -	———	Fluke, hydatid, tape-worm.
	3. ACALEPHÆ - - -	———	Actinia, medusa.
	4. POLYPI - - -	———	Hydra, coral, madrepore, pennatula.
	5. INFUSORIA - - -	———	Brachionus, vibrio, proteus, monas.

GRANT'S DIVISION OF THE ANIMAL KINGDOM.

Division.	*Class.*		
I. CYCLO-NEURA VEL RADIATA	1. POLYASTRICA	*Exam.*	Monad, madrepore.
	2. PORIFERA - -	———	Sponges.
	3. POLYPIFERA -	———	Polypes, corals.
	4. ACALEPHÆ - -	———	Medusa, actinia.
	5. ECHINODERMATA	———	Star-fish, sea-urchin.

Division.	*Class.*		
II. DIPLO-NEURA VEL ARTICULATA.	6. ENTOZOA	*Exam.*	Intestinal worms, hydatids.
	7. ROTIFERA	——	Patella.
	8. CIRRHOPODA	——	Barnacle, triton.
	9. ANNELIDA	——	Earth-worm, leech,
	10. MYRIAPODA	——	Scolopendra.
	11. INSECTA	——	Bee, butter-fly.
	12. ARACHNIDA	——	Spider, scorpion.
	13. CRUSTACEA	——	Lobster, crab.
III. CYCLO-GANGLIATA VEL MOLLUSCA.	14. TUNICATA	——	Ascidia intestinalis.
	15. CONCHIFERA	——	Muscle, oyster.
	16. GASTEROPODA	——	Slug, snail.
	17. PTEROPODA	——	Clio, hyalœa.
	18. CEPHALOPODA	——	Cuttle-fish.
IV. SPINI-CEREBRATA VEL VERTEBRATA.	19. PISCES	——	Salmon, shark, eel.
	20. AMPHIBIA	——	Frog, toad, proteus.
	21. REPTILIA	——	Tortoise, lizard, serpent.
	22. AVES	——	Eagle, heron, duck.
	23. MAMMALIA	——	Man, kangaroo, whale.

Many other arrangements of the animal kingdom have been proposed by different zoologists; some, as Linnæus, founding their basis of classification on the vascular and respiratory systems, and others on the peculiarities afforded by the generative organs. Aristotle divided all animals into those with, and those without red blood; and Lamark into the apathic, the sensitive, and the intelligent.

CHAPTER II.

SKELETON IN THE INVERTEBRATA.

General observations.—The skeleton gives figure, strength, and solidity to the entire frame; it serves as a basis of support to the soft parts, forms levers of locomotion, and encloses cavities to protect and defend the most delicate and important organs. Its use, however, being chiefly of a mechanical nature, it will be found to vary much, according to the respective wants, habits, and instincts of animals. In all the operations of nature we find that there is a rigid economy observed; the means employed are such only as are required, and always the most simple by which the intended purposes can be accomplished. Hence we shall not be surprised to meet with infinitely varied modifications of skeleton throughout the widely extended range of the animal world. The chemical composition of this solid frame-work presents some variety. For instance, silica is found in the lowest forms of the radiata; carbonate of lime in the molluscous animals; carbonate and phosphate of lime in the articulata; and phosphate of lime in the organised skeletons of the vetebrata. This frame-work is sometimes placed external to the soft parts, and in others it is internal to them. In no instance do we meet with a bony skeleton except in animals possessed of

a regularly formed brain; and here it is obvious to those who understand the difference between the growth of shell and bone that the former would be unfit for the purpose, since there is no provision made for the enlargement of the original cavity.

Radiata, Cuvier; *Cyclo-neura*, Grant.—In this acrite or lowest division of the animal kingdom the skeleton generally holds an internal situation, and is composed either of one large mass or several smaller pieces symmetrically disposed, composed of silicious or calcareous spicula. In many of the *polygastrics* the organ of support consists in a condensation of the common integument enveloping the body—occasionally in the form of an elastic vaginiform sheath into which the animal can retreat on the approach of danger, &c., as seen in the vaginicola innata. Among the *poriphera*, skeletons are met with of a horny, silicious, or calcareous structure, variously modified. In none does nature seem to have amused herself more in the construction of skeletons than among the *zoophytes*. Here they are met with internal or external, soft, horny, or calcareous; branched, globular, or filiform; free or fixed. The asterias and others of the *echinodermata* present us with skeletons in the form of external crusts or shells, disposed after the manner of plates, and composed of carbonate, with a trace of phosphate of lime.

Articulata, Cuvier; *Diplo-nerose Animals*, Grant.—The bodies of these animals are generally long, cylindrical, and divided transversely into segments. Their skeletons are generally thin, light, and situate externally, chiefly composed of phosphate of lime, though occasionally of carbonate, as in the cirrhopoda and crustacea. The *entozoa* owe their peculiar stiffness and rigidity to the tough, strong, and transparent covering enveloping their entire body. In some of the inferior orders of them, as in the acanthocephalous species, their retractile proboscis and part of their bodies are set with dense, sharp spines, which enable them to move with freedom and precision through the fleshy media in contact with them. The *rotifera* are closely allied to the entozoa in their exterior coverings. In the former, however, this texture possesses a greater degree of firmness, from the attachment of numerous muscles to it. There are no earthy deposits in any part of the body of these animals. The *cirrhopoda*, like the mollusca, are usually enclosed in shells, dense, thin, laminated, and composed of carbonate of lime. These testaceous coverings are best developed in the balani, and least in the anatiferæ. The reverse order of development obtains with respect to their extremities.

The *annelida*, or red-blooded worms, lead us a step higher in the development of skeleton; for, although the halithea, the leech, the nais, &c., possess a flexible membraneous covering, many others, as the serpulæ, are shielded by adventitious, solid, calcareous tubes. The common earth-worm is provided with four pairs of sharp spines, or setæ, for the purpose of progression. The skeleton of *insects* is for the greater part composed of a thin, epidermic layer,

and a thick internal one resembling the woody fibres of plants, but of an animal nature, termed *chitine* and *coccine*, blended with portions of phosphate of lime, magnesia and iron. These animals also present distinct legs and wings.

In the *arachnida* we meet with a more consolidated form of skeleton; generally more than three pairs of legs; and, at the sides of their head, a pair of sharp-pointed piercing instruments, suited to their retired, cunning, and carnivorous habits. These animals throw off periodically their exterior coverings, like the larvæ of insects; and, like the crustacea, they are capable of reproducing their members when destroyed. The *crustacea* affords us by far the most solid form of skeleton met with in any of the articulata. In the decapods it contains half its weight of carbonate of lime, and a considerable proportion of phosphate, with traces of iron, soda, and magnesia, all of which are secreted from the true skin. These animals have generally five pairs of legs, two strong mandibles, two pairs of slender maxillæ, and two pairs of antennæ. The solid crust forming the skeleton of crustacea is cast off periodically. This is accomplished by the animal first detaching the cutis and muscles from the inner surface of the old shell; then secreting from the surface of the cutis a new layer of epidermis; next a layer of colouring matter; and, within this, the calcareous materials of the new shell.

Mollusca, CUVIER; *Cyclo-gangliated animals*, GRANT. The shells of these animals are formed of carbonate of lime, without the phosphate, and are remarkable for their want of symmetry on the two sides of the body, and their inconstancy in animals of similar structure. In the *tunicata* we meet with an exterior cartilaginous skeleton, in some instances thick and opaque, as in the ascidia —in others more delicate and transparent, as in the cynthia papillata. The shells of the *conchifera* usually consist of two movable pieces placed on the exterior of the body, connected by ligament and muscle. All these animals, however, are not bivalved; some, as the pholades, have additional pieces at the hinge of the valve, constituting the multivalves. They have a muscular foot, and a pair of tentacula. The *gasterpoda* possess hollow, unilocular, conical shells. Many of them have no shell, as the tritonia and doris; some have a thin calcareous lamina within the skin of the back, as the aplysia; whilst others have only a partial covering of shell as the testacella. In the *cephalopodous* mollusca we recognise the transition from the external unorganised shells of the invertebrated tribes to the internal organised bones of the vertebrata. The shells are sometimes external, as in the nautilus, and sometimes internal, as in the sepia. In this complicated class of animals we find a near approach to the cartilaginous fishes in the presence of cranium, spinal column, &c., in a rudimental form.

RECAPITULATION.

1. All animals are included under the heads *vertebrata* and *invertebrata.*
2. Great advantage to be derived from a knowledge of arrangement and classification.
3. The osseous system is neither the most important nor the most uniformly existing.
4. Skeleton exists in every *class* of animals, but modified according to each class.
5. Skeleton generally internal in the radiata, and external in the articulata, subject to exceptions.
6. Skeleton remarkable for inconstancy and want of symmetry in the mollusca.
7. Basis of skeleton—silica in the lowest radiata, carbonate and phosphate of lime in the articulata, and carbonate of lime chiefly in the mollusca.
8. No bony skeleton where regularly formed brain does not exist.

CHAPTER III.

VERTEBRATA.

General observations.—It will appear hereafter that the principal part of the nervous system consists in a single central mass extended along the back, and composed of a series of distinct portions, each of which, like the cerebral ganglion of one of the sepiæ, is indicated by its giving off one or more pairs of nerves. To coincide with such a disposition, the chief portion of the skeleton is formed by a series of osseous rings, which being mutually articulated and collectively forming a closed cavity, compose a series of spinal vertebræ constituting the spinal column—the distinctive character of this division of the animal sphere. The vertebral column, which is the first rudiment of skeleton observed in the human embryo, is also the primary and most essential portion of it in the higher classes of animals generally, and in many cases alone composes nearly the whole of the skeleton.

Another characteristic of the skeleton in this department of animals is, that it is placed internal to the soft parts, and is not exuviable in a mass, as it was in most of the invertebrate classes. Here the phosphate of lime is the predominant ingredient, and its proportion increases as we ascend through the vertebrated classes.

The appearance of the skeleton is greatly varied by the situation of the ribs; for instance, in fish and aquatic mammalia the thorax is placed near the anterior part of the column, to allow of the mobility

of the posterior portion for the purposes of swimming. In birds, where the neck is used as a prehensile organ, the thoracic portion of the column is situate near its posterior extremity. Whilst in quadrupeds and reptiles balanced on two pairs of extremities, the solid portion of their trunk is placed near the middle of their column.

PISCES.

The bones of fishes closely resemble those of the higher grades of organisation in their embryotic state, not only in their soft cartilaginous character, but also in the isolated condition of their several centres of ossification, especially in the complicated bones of the head. The bones of the cartilaginous tribes are composed of water, gelatine, and the sulphate, subcarbonate and chloruret of soda; whilst the more dense bones of the osseous fishes are indurated and strengthened by the more insoluble phosphates. As the human embryo originally consists almost exclusively of the vertebral column, so also in fishes we find that the spine, and the head, which is only an increased development of it, constitute the most important parts of the skeleton.

Spine.—The vertebræ in this class are very numerous, and may be divided into the abdominal and caudal. The bodies of the vertebræ are the elements first developed; they are the most important, and form almost the entire of the skeleton in the lowest species of cartilaginous fishes. They are concave on both surfaces; consequently enclose large spaces, filled with a thin gelatinous fluid; and in many of the cartilaginous species, the inter-vertebral substances communicate and form a continuous elastic chord passing through the entire column as in the lamprey. The spinous processes of the abdominal vertebræ are very long superiorly, and assist, by their shanks, to form the spinal canal; whilst the caudal vertebræ are distinguished by having long spinal processes both above and below. Between the roots of the inferior spinous processes there is enclosed a similar canal, but larger for the passage of the great systemic artery.

The vertebral column in fishes is constructed in such a manner as to give considerable perpendicular extent to the trunk, and thus favour their horizontal mode of progression. The number of *vertebræ* varies greatly; thus in the carp we find 41, in the burbot 57, in the eel 115, and in the shark as many as 207. In the osseous fishes, the *ribs* form an upper and a lower range; the latter are better developed and more uniform in their existence than the former. The number of ribs is generally determined by that of the abdominal vertebræ. In some, however, as the chætodon, scomber, &c., the caudal vertebræ are furnished with ribs. These bones articulate with one vertebra only, as a consequence of which they enjoy but little motion, and are but slightly subservient to respiration. In the shark they are cartilaginous; in the carp they are long and firm; in the eel short and slender; and in many genera, as the raia, fistularia, &c., they are almost wholly absent. The *sternum*, when

present, consists, as described by Meckel, of a variable number of V-shaped pieces, pointed downwards and overlapping each other. This rudimentary bone is best seen in the herring and the dory.

Head.—To the researches of Oken, Meckel, Carus, Blainville, &c., we are indebted for the important fact that the cranium, is nothing more than a highly developed portion of the vertebral column. The composition of the cranium in the cartilaginous fishes is very simple; in many, as in the skate, consisting chiefly of one large piece. In the osseous tribes, on the contrary, the component parts are very numerous—amounting to 80 in the head of the perch. The bodies of the vertebræ continue forward in a straight line with the spine along the base of the scull, forming the basilar part of the occipital, the body of the sphenoid, and the ethmoid bones. In the bony fishes the cranium is remarkable for being thin, diaphanous, elastic and having its elements united by squamous sutures, which favours the extension of the period of growth of each part. The cavity of the cranium is occupied chiefly by the cellular tissue of the arachnoid coat; the brain occupying but a small portion of the base of the skull.

The bones of the face present but few peculiarities. The intermaxillary bone consists of three triangular pieces inserted between the vomer, the palate, the nasal, and the superior maxillary bones. The central piece is generally cartilaginous. In connection with the upper jaw, we have to notice the os quadratum; this is composed of several pieces, which closely resemble the ascending process of the lower jaw in man. The three portions of which it is mainly composed are articulated, one to the inferior maxilla and palate bone, the second to the temporal bone, while the third consists of a thin round plate, and is called os discoideum. Behind the lower jaw, and connected to the os quadratum, is the operculum. This is a plate of bone usually composed of four pieces, which have been considered analogous to the bones of the tympanum, on account of the absence of this cavity from the ears of fishes; others have regarded it as a portion of the lower jaw. Be this as it may we find the operculum covering the respiratory apparatus in the same manner as the shells of bivalves cover the subjacent gills.

The os hyoides reaches a high degree of development here, as in all water breathing vertebrata; it consists of a body or lingual bone, and five pieces on either side of it: it is suspended from the temporal bones; and it is, by its free antero-posterior motions that respiration is effected in fishes, and in amphibia, as will be shown hereafter. It forms an arch, having the lower jaw above it, and the scapular and coracoid bones below. Its sides support the four pairs of branchial arches, and externally it has attached to it the opercular membrane.

Extremities.—In fishes fins supply the place of extremities; the anterior corresponding to the arms, and the posterior to the legs. They are named according to the parts they are attached to, as dorsal, pectoral, ventral, caudal, and anal fins. The anterior or

pectoral fins are larger and more uniform in their existence than the posterior; they also commence their development at an earlier period; in all of which they resemble the embryo of the higher classes. The ventral fins are wanting in the apodes, as well as in several species of other orders; whilst the pectoral fins are generally present.

The anterior fins are generally joined to the back of the skull by means of an osseous belt, formed behind by the scapula, and in front by the coracoid bones. A humerus, generally long and angular, is attached to these above, and to the radius and ulna below. To these succeed the carpal bones, and the member is terminated by long and numerous phalanges. The posterior members, or ventral fins, have no connection to the spine, but are suspended from the rib-like iliac bones, and placed on the lower part of the trunk, at a variable distance between the head and anus. The presence of a sacrum in this class would be injurious to the free motion required in swimming. In the abdominal fishes the pelvic bones are unconnected to the skeleton; and in the apodal families they are wholly absent. The long phalanges of the feet are attached directly to the pelvic bones, there being rarely a trace of intermediate bones developed.

The want of symmetry observed in the skeletons of many fishes forms a singular peculiarity in this class. In the pleuronectes, for instance, one side is turned upwards, instead of the back; both eyes are placed on the same side; the cranial vertebræ seem twisted in their long axis; and the lower part of the head is imperfectly developed. The bones, especially the intermaxillary, are much larger on the side opposite to that on which the eyes are placed.

RECAPITULATION.

1. The bones of fishes resemble the embryotic condition of the osseous system in the higher classes of animals.
2. The spine is the most important part of their skeleton.
3. The spinal column enjoys very free motion, chiefly in the lateral direction.
4. The construction of the head is as simple in the cartilaginous, as it is complex in the osseous fishes.
5. The os hyoides is greatly developed to support the branchial apparatus.
6. The anterior fins are larger, earlier developed, and more uniform in their existence than the posterior.
7. The pelvic bones and posterior fins are absent from the skeletons of many cartilaginous fishes.
8. Want of symmetry is a striking peculiarity in the skeletons of many fishes.

AMPHIBIA.

In the *Batrachia* the ribs are almost wholly absent; it is only in the rana pipa and the salamanders that small cartilaginous appendages are found attached to the transverse processes of some of the vertebræ. In these animals the spine consists of dorsal, sacral, and caudal portions—the distinction being marked by the connection of one of the vertebræ to the ilium on each side. The salamander has fourteen dorsal, one sacral, and twenty-seven caudal vertebræ; in the common frog there are only nine vertebræ; and in the rana pipa but eight; whilst the siren has forty-three in the trunk, and about forty-five in the tail; from the second to the eighth inclusive have rudimentary ribs attached to them. The bodies of the vertebræ are concave on their surfaces; so that, when in apposition, they give rise to the existence of an intervertebral oval cavity filled by a gelatinous mass.

When we consider the habits, food, and mode of progression, of the *frog*—that its movements, which are chiefly on land, are both active and extensive, as well for the purpose of seizing its prey as of escaping from danger—it becomes obvious why its spine should be short and firmly anchylosed—how the presence of a tail would be worse than useless, and why a necessity exists for a full development of the posterior extremities. The absence of ribs will hereafter be accounted for by an interesting peculiarity in the function of respiration.

Cranium.—The elements composing this cavity are remarkable for remaining permanently ununited, a state of things which is strikingly imitated during the progress of the development of these parts in the higher orders of animals. The maxillary, intermaxillary, tympanic, and jugal bones are greatly expanded, in the transverse direction, giving the face a flattened appearance. The lower jaw consists of three pieces on each side.

Of all parts of the osseous system of this class, there is none so interesting as the *os hyoïdes*, on account of the changes to which it is subjected during the transit of the amphibia from the pisciform to the reptile state. The branchiæ are external, supported by cartilaginous arches connected with os hyoides. As the age of the tadpole increases, the branchiæ disappear, the lungs become developed, and the os hyoïdes grows, from a small rhomboidal point, to the large size and peculiar from which it presents in the full-grown frog.

Anterior extremity.—The shoulder of a frog consists of scapula, clavicle, and coracoid bone, all of which unite to form the glenoid cavity. The humerus is short and thick, having a round head above, received by the glenoid cavity, and also a spherical extremity below, to articulate with the bones of the fore-arm, which consists of radius and ulna so united that a faint line indicates their former separation. The carpal bones are six; the metacarpal, four. The

middle and index fingers have each two phalanges, the others three.

The *posterior extremity*, for reasons before assigned, reaches a high degree of development. The cotyloid cavity is constituted by the ilium, ischium, and pubis. The femur is long and cylindrical. The tibia and fibula are consolidated into one bone, and joined inferiorly to two bones representing astragalus and os calcis. Between these and the long metatarsal bones are placed four small, irregular bones. Of the five toes, the internal is best developed, and sustains three long, slender phalanges.

The structure and form of the salamander, proteus, and siren, are well contrasted with those of the frog. In the former animals, the spinal column attains a high state of development: the extremities are reduced to a rudimental type. The bones of the fore-arm and leg, instead of being anchylosed as in the frog, maintain a permanent state of separation. The toes, which are four in number, are but slightly developed. The whole economy of the frog is admirably organised for rapid terrestrial progression, while that of the other animals is designed to favour their movements through a watery element.

Who can fail to observe the extreme wisdom manifested in the metamorphosis of these animals? In the early part of their existence, and while they enjoy an aquatic mode of life, their organisation is in due accordance; at first their members are scarcely perceptible, whilst their tail is of great length, and continues so in those destined to continue their watery habitation; but in the frog, &c., which are to breathe by lungs, the tail is gradually removed by absorption, and the extremities, particularly the posterior, undergo a rapid evolution.

REPTILIA.

Chelonia.—These reptiles present a tolerably perfect form of skeleton. Their *spine* consists of eight cervical, fourteen dorsal, three sacral, and from twenty to thirty caudal vertebræ. There are eight pairs of immovable *ribs*, united to each other by sutures, and attached between the bodies of the vertebræ. By the union of the ribs with each other, and with the spinous processes of the dorsal vertebræ, they form the upper shield or carapace. The nine pieces of the *sternum* which are movable in the turtle, form the lower shield or plastron. This unyielding frame-work is well suited to resist pressure, as well as to favour their muscular movements on land, whilst the mobility of the several elements of the sternum in the aquatic species is applicable to their extensive respiration in that dense element.

The bones of the *head* are firmly united by sutures. The occipital condyle presents three facets, formed by the basilar and the two condyloid portions. The inter-maxillary bones are narrow, but present a large palatine surface. The bones of the ear are

anchylosed, and the body and cornua of the os hyoides are fully developed.

In the *anterior extremity*, which is attached to the inner side of the chest, we distinguish scapula and clavicle united by suture; humerus twisted, with a large articular condyle; radius and ulna short, strong, and expanded inferiorly, fixed in a state of pronation; carpal bones, sometimes as many as ten, arranged in three rows; five short metacarpal bones; and the phalanges, two for the thumb and last finger, and three for each of the others.

The ilia are long and cylindrical in the land tortoise; the pubis and ischium broad and flat. The femur presents indications of trochanters, as in man; its head is large, and joins the shaft at a right angle. There is no round ligament in the hip, though rudiments of semilunar cartilages connected to crucial ligaments in the knee. The tibia and fibula are separate. The metacarpal bones are five, and the number and arrangement of the phalanges the same as observed in the phalanges of the fingers, with the exception of the outer toe, which is generally rudimentary. In the aquatic chelonia, the bones of the extremities are longer, straighter, and more slender than in the land species.

Ophidia.—The skeleton in serpents consists of little more than a vertebral column, possessing such a degree of mobility as enables them to creep with speed along the surface, to swim through the waters, to spring into the air, to climb trees, and to combat with and conquer their prey. Extremities are here wholly absent, and the spinal column and ribs constitute the sole organs of progressive motion. For this reason the spine is characterised by immense strength and great mobility. The vertebræ are more numerous in this than in any other class of animals, being 49 in the anguis fragilis, or blind worm; 201 in the crotalus horridus, or rattle-snake; and 316 in the coluber natrix. The bodies of the vertebræ have ball and socket articulations, so disposed as to admit of free lateral, but limited antero-posterior motion. The *ribs* of serpents are tubular, narrow and compressed from before backwards. Their head presents a broad, arched, concave surface, to articulate with the rounded, prominent, transverse processes of the vertebræ, whilst their ventral extremity tapers to end in a thin, flexible cartilage. The ribs extend from the atlas to the anus, and are 32 pairs in the blind worm, 175 in the rattle-snake, and 204 in the coluber natrix. They are all of the false kind, there being no rudiment of sternum, except in the ophisaurus and blind worm alone, in which also faint traces of shoulder and pelvis may be discerned.

The *head* resembles the preceding order (or that of the chelonia) in the small size of the cranium, whilst the multiplicity and detached condition of its bones ally it to the fishy tribes. This loose state of the component elements of the head is necessary in serpents, for, being deprived of organs of prehension, they are compelled to swallow their prey entire. As a consequence of the looseness of the other bones, the two parietals are anchylosed along the median line, to

protect the brain during the exposure of these animals to the trampling of quadrupeds, &c., whilst concealed in their natural haunts. Their teeth are small, conical, and sharp; they are placed in the two maxillary, the intermaxillary, and the palate bones.

Sauria.—In this order we meet with a more perfect development of skeleton than in the last, as they possess a sternum, a scapular and pelvic apparatus, together with atlantal and sacral extremities. The lacerta iguana presents 5 cervical, 11 dorsal, 9 lumbar, 2 sacral, and 72 caudal vertebræ; the crocodile of the Nile 7 cervical, 12 dorsal, 5 lumbar, 2 sacral, and 34 caudal—articulated by ball and socket. There are false *ribs* behind and before the true ones. In the chameleon there are 17 pairs; in the crocodile 12. The *sternum* is prolonged posteriorly as far as the pubis, and has attached to it five pairs of cartilaginous arches, for the purpose of supporting the abdomen.

The *head* is extended forwards in a line with the spine, as in the other inferior vertebrata; like these, also, its component elements are loosely connected. As in serpents, the basilar condyle is elongated transversely, and the parietal bones anchylosed. The lower jaw consists of six pieces on each side; and here, as in serpents, the prehensile teeth are attached by broad base to the surface of the jaw, and the new teeth rise by the side of the old, and not in their interior as in the crocodile.

Anterior extremity.—The scapula is broad, thin, and curved. The acromion is a distinct bone, and the clavicles are anchylosed in form of a cross, on the front of the sternum. The humerus is expanded at its extremities, and the same form as in man; the ulna is without an olecranon, stronger than the radius, and separated from it below. There are from four to nine bones in the carpus, five in the metacarpus; and the phalanges are, two for the thumb, three for the second and last fingers, and four for each of the others.

Posterior extremity.—The three portions of the os innominatum contribute to the formation of the cotyloid cavity. The ossa pubis and ischii form a lengthened symphisis in front; and the spine of the iliac bones is extended backwards along each side of the sacrum. From the front of the pubic bone a process passes up towards the sternum as in the marsupiales. The head of the femur is compressed and directed forwards; the great trochanter is also flat and turned towards the tibia. The patella is small; the tibia short, thick, and curved; the fibula slender in the centre, expanded at its extremities, and apart from the tibia. In the crocodile there are five bones in the tarsus, four in the metatarsus, and the toes are so arranged that the most internal sustains two phalanges, the second three, and the third and fourth, four each.

In the skeletons of the nilotic crocodiles, alligators, and other reptiles destined to swim by the lateral movements of a muscular tail and long webbed feet, their long bones are filled with a thin oily marrow, and the bones of the head firmly united.

RECAPITULATION.—*Amphibia.*

1. *In amphibia* rudiments of ribs only are met with.
2. Vertebræ range from eight in the rana pipa to eighty-nine in the siren.
3. In the frog, the extremities, especially the posterior, are fully developed; the tail is absorbed.
4. Salamander, proteus, and siren, may be well contrasted with the frog; in the former the spinal column attains and maintains a high degree of development, whilst their members are reduced to a mere rudimental type.
5. The bones of the cranium remain loosely united through life.
6. The os hyoides undergoes remarkable changes during the metamorphosis of the animal from the pisciform to the reptile state.

RECAPITULATION.—*Reptilia.*

1. The vertebræ and ribs are more numerous than in any other class of animals.
2. The chelonia differ from the sauria in having immovable ribs, and from the ophidia in having arms and legs.
3. The bones of the head generally maintain a permanent state of separation, except the parietals which are firmly anchylosed.

AVES.

As in this department of my subject I avail myself of much of the valuable matter contained in the article, Aves, in the Cyclopædia of Anatomy and Physiology, by that clear, accurate, and scientific writer, Mr. Owen, it becomes necessary to state that he divides the class into the following orders:—

1. Raptores, birds of prey, or raveners; 2. Insessores, perchers; 3. Scansores, climbers; 4. Rasores, scratchers; 5. Cursores, coursers; 6. Grallatores, waders; and 7. Natatores, swimmers.

Positive characters of the class.—Animal, vertebrated, oviparous, biped; anterior extremities organised for flight; integument plumose; blood red and warm; respiration and circulation double; lungs fixed and perforated.

Negative characters.—No auricles, teeth, lips, epiglottis, diaphragm, fornix, corpus callosum, or scrotum.

The bones of birds are remarkable for being permeated by atmospheric air, for their compact and laminated texture, their white colour, and their fragility, owing to a preponderance of phosphate of lime.

The *vertebræ* are the first bones observed in the development of the osseous system of birds, and of all parts of this system, they present the fewest variations. The spine here consists of cervical, dorsal, sacral and caudal portions. The first and last are the most

movable, and in many species of the dorsal and caudal portions admit of no motion at all. This fixity facilitates the flight of the bird, whilst the length and mobility of the cervical portion of the spine compensate, in some degree, for the unfitness of the anterior members to the purposes of prehension, &c.

The *cervical* portion of the spine is generally composed of a greater number of vertebræ than any of the other divisions; they are not fewer than nine, as observed in the sparrow, nor more than twenty-three, as in the swan.

The bodies lock into each other, and are so disposed as to allow the superior and inferior ones to move forwards, and the middle backwards. The transverse processes are long, and have rudimentary ribs connected to them; these are particularly well developed in rapacious birds, and hence the great breadth of their necks. The atlas is a simple ring, generally articulated to the occipital tubercle by a single facet; but the penguin and ostrich have two other facets continuous with the central one. From the dentata down, a movable inter-articular cartilage is found, as in the joint of the lower jaw of the mammalia.

The *dorsal* vertebræ range from six in the bull-finch to eleven as seen in the swan. The bodies of these vertebræ are short and compressed laterally, except in the ostrich. The transverse processes are greatly developed. The anterior cartilaginous surface is convex in the vertical direction, concave in the transverse, and connected by fibrous capsules and synovial membranes. Most birds have the middle and lower vertebræ anchylosed; even the transverse and spinous processes of the superior are anchylosed in those birds requiring great fixation of the trunk; while in those that cannot fly, as the penguins, they are all movable.

The *sacral* vertebræ are firmly anchylosed with one another, and with the ilia laterally; consequently it is difficult to determine their real number; it is not, however, greater than nineteen, as seen in the emeu and cassowary, nor less than eight, as observed in the hoopoe. The bodies of these vertebræ are broad, but shallow, and the canal greatly enlarged, to correspond to the size of the chord, which here supplies nerves to the posterior extremities. When it is considered that the head, posterior members, viscera, &c., are suspended in flight from this central portion of the trunk, the necessity for the mechanism consolidating these vertebræ will be readily appreciated.

The *coccygeal* vertebræ are generally movable, and from five to nine in number. With the exception of the last, they are broad, short, and perforated for the spinal marrow. The last has no processes; it is compressed laterally, and terminates above and below in a sharp edge; it supports the coccygeal oil-gland, and affords a firm basis to the tail feathers, or *retrices* of Linnæus. These bones possess ligamentous connections, except the sixth and seventh which re provided with a capsule and synovial fluid.

TABLE OF THE VERTEBRÆ IN BIRDS.

Species.	Cerv.	Dor.	Sac.	Cau.
ORDER RAPTORES.				
Vulture,	13	7	11	7
Eagle,	13	8	11	8
Sparrow-hawk,	11	8	11	8
Kite,	12	8	11	8
Hawk-owl,	11	8	11	8
ORDER INSESSORES.				
Fly-catcher,	10	8	10	8
Blackbird,	11	8	10	7
Crow,	13	8	13	7
Magpie,	13	8	13	8
Jay,	12	7	11	8
Starling,	10	8	10	9
Bull-finch,	10	6	11	6
Sparrow,	9	9	10	7
Goldfinch,	11	8	11	8
Lark,	11	9	10	7
Redbreast,	10	8	10	8
Swallow,	11	8	11	9
Humming-bird,	14	9	10	8
Kingfisher,	12	7	11	7
ORDER SCANSORES.				
Woodpecker,	12	8	10	9
Parrot,	11	9	11	8
ORDER RASORES.				
Pigeon,	13	7	13	7
Peacock,	14	7	12	8
Pheasant,	13	7	15	5
Turkey,	15	7	10	5

Species.	Cerv.	Dor.	Sac.	Cau.
ORDER RASORES.				
Crested Curassow,	15	8	10	7
ORDER CURSORES.				
Ostrich,	18	10	17	9
Cassowary,	16	10	19	7
Emeu,	19	9	19	9
ORDER GRALLATORES.				
Heron,	18	7	10	7
Crane,	19	9	12	7
Spoonbill,	17	7	14	8
Avoset,	14	9	10	8
Plover,	15	8	10	7
Woodcock,	18	7	13	8
Curlew,	13	8	10	8
Oyster-catcher,	12	9	15	7
Coot,	15	10	13	8
Flamingo,	18	7	12	7
ORDER NATATORES.				
Pelican,	16	7	14	7
Cormorant,	16	9	14	8
Gull,	12	8	11	8
Catarrhactes,	13	9	13	8
Swan,	23	11	14	8
Goose,	15	10	14	7
Duck,	14	8	15	8
Sheldrake,	16	11	11	9
Mergancer,	15	8	13	7
Grebe,	14	10	13	7

Skull.—It has been already shown that the bones composing the skull of the crocodile, and other cold blooded vertebrata, were not consolidated till a late period of life, giving rise to some difficulty in tracing a correspondence between their bones and those of a higher order. A still greater difficulty is experienced in determining the component parts of the head in birds; for in them the bones of the skull are anchylosed, and every trace of suture effaced at an early epoch; therefore, in order to accomplish their perfect separation, it must be undertaken at an early period of their existence.

In the majority of birds, the head is articulated to the spine, by means of a single hemispherical tubercle on the basilar process of the occipital bone; but in the penguin and ostrich, the condyloid portions contribute to its formation, and the articulation is such as to admit of very great freedom of motion.

The occipital bone is originally composed of four pieces, basilar, spinous and two condyloid. The temporal consists of the petrous, squamous, and tympanic portions; the last is movably articulated to the inferior part of the squamous portion, and is sometimes called os quadratum. The alæ majores of the sphenoid bone remain a long time separate, and are called interarticular, or omoid bones. The remaining bones of the skull present no remarkable peculiarities

save that they are all early and firmly anchylosed, with the exception of the tympanic bone.

The bones of the face correspond in number and position to those of the mammalia, especially the order rodentia. They are movably connected with the bones of the cranium, and remain separate to a much later period. The upper mandible is chiefly characterised by the presence of the intermaxillary bone. This consists of three processes, a central, and two lateral; the former passes up between the superior maxillary bones, and becomes joined to the nasal and ethmoid; this union is ligamentous in the parrot, and those birds that apply the upper mandible to the purposes of climbing. The two lateral processes of the inter-maxillary bone, extend upwards and backwards external to the superior maxillary bones, to which they are firmly united.

There are few more ingenious or beautiful pieces of mechanism than that by which the mouth of a bird is opened. The tympanic bone as before observed, never anchyloses with the other elements of the temporal; on the contrary, it articulates with the zygomatic portion of the latter bone, by two transverse condyles above; below it articulates by a broad surface with the upper and back part of the lower jaw, while in front and near its lower extremity, it has applied to it the long, slender malar bone which reaches to the superior maxilla. When the tympanic bone is drawn forwards, either by the action of the pterygoid muscles attached to it, or by the depression of the lower jaw, the malar bone is advanced against the superior mandible, which is elevated at the same moment that the lower one is depressed. The moment the pressure ceases to exist below, the elasticity of the union of the intermaxillary bone with the cranium restores the upper mandible to its situation.

The *inferior maxilla* originally consists of six pieces on each side, named anterior dental, two condyloid, angular, supra-angular, and opercular. As this bone, together with the upper jaw, forms the chief organ of prehension in birds, it is but natural to expect that it shall present numerous modifications, indicative of the food and habits of each species.

There is more uniformity observed in the skulls of birds than in any other class of the vertebræ department. It generally presents the form of a five sided pyramid, the base represented by the occiput, and the apex by the bill. In the Raptores it is short, broad, and deep; nearly spherical in the Warblers; flattened, and of great breadth, in the Scansores; narrow, and slightly raised in the Rasorial birds; and remarkable for its great length in the Waders.

Thorax.—The extent and energy of the respiratory function of birds, are clearly indicated by the peculiar and perfect condition of this part of their osseous system. The *ribs*, as in the mammalia, are arranged into true and false, with this difference, that the false ribs are placed both above and below the true ones. There is some, though not very great variety in the number of ribs presented by this class: for instance, in the Insessores we meet with seven or

eight pairs; and in the willock, of the order Natatores, twelve pairs; the average number is eight or nine pairs. The true ribs are joined to the sternum by straight osseous portions, called sternal ribs, instead of by elastic cartilages, and are movably connected at each end. It is highly interesting to observe the mode of articulation of the vertebral extremity of the ribs. In such as require fixity of the chest, for the purposes of flight, the rib is articulated to the side of the vertebra, having no connection to the inter-articular cartilage; but in the ostrich, and others of the cursores, where the dorsal vertebræ preserve their mobility, the heads of the ribs are attached to the intervertebral spaces.

There is another interesting fact connected with the ribs, in birds of powerful flight; it consists in a number of small osseous plates being detached from the posterior margin of each true rib, and passing backwards and upwards to be connected to the succeeding rib, by means of strong, oblique, fibrous ligaments. In the ostrich, rhea, emeu, and cassowary, these bony splints present a mere rudimentary type.

Sternum.—The modifications presented by this bone, strictly conform to the functions which the anterior extremities are designed to execute. Hence, in the cursorial birds which do not fly, it is met with in the form of a simple square plate of bone like a shield, while in those birds that possess great powers of flight, it extends over the whole of the lower aspect of the thorax and abdomen, even to the pubic bones, and in order to afford sufficient space for the attachment of the pectoral muscles, it is armed with a huge crest, extending the whole length of its lower surface. This crest, or keel, is uniformly developed in proportion to the size of the pectoral muscles, and hence declares the power of the anterior extremities. The sternum is sloped obliquely on each side of its anterior extremity, for the reception of the clavicle, and in the centre is connected with the fork-bone, either directly or by means of ligaments; the true ribs are attached to it on each side. The sternum of the crane has within it a large cavity, containing several convolutions of the trachea. This condition is repeated in the wild swan; but in the tame swan, and some of the grallæ, as the ciconia and gallinæ, it is but very feebly developed.

On the internal surface of the sternum, chiefly along the mesial line, several apertures may be observed, for the passage of air into the bone.

Anterior extremity.—Here, as in the mammalia, the extremity consists of shoulder, arm, fore-arm, and hand. In the first, we recognise a scapula, a coracoid bone, and a clavicle.

The *scapula* is generally a long, narrow bone, increasing in thickness as it approaches the shoulder joint, where it expands in the transverse direction, to form the posterior half of the glenoid cavity; here also it articulates with the coracoid bone and clavicle. The direction of the scapula is longitudinal. In birds with active

powers of flight, it reaches to the last rib, while in the emeu it covers only two. This bone is broad and flat in the penguins.

The *coracoid*, or posterior clavicle, is a strong bone, broad inferiorly, where it is received in a transverse groove in the sternum; it extends upwards, outwards, and forwards, to articulate with the scapula and clavicle. The glenoid cavity thus resulting from the union of this bone with the scapula, is often unequal to the reception of the head of the humerus; hence, in the raptores and insessores, a small but distinct bone extends between the coracoid and scapula, over the superior part of the cavity, which it here completes. It was discovered by Nitzsch, who called it the capsular bone.

The *clavicles* are subject to considerable variety. In the ground parrots of Australia, for instance, they present only a rudimentary type, while in the psittacus mitratus, &c., they are wholly absent; they are feebly developed in the emeu, rhea, and cassowary. When these bones are enchylosed together at their sternal extremities, as they ordinarily are, they constitute a single bone, named furculum. In the ostrich they do not come in contact inferiorly, although they reach the sternum; and in the toucans, they neither come in contact below, nor reach the sternum. It is remarkable that in the ostrich they are anchylosed above with the coracoid and scapula, whilst almost in every other species they either continue separate, or are movably jointed superiorly.

The *humerus* attains its greatest length in the albatross, and is shortest in the struthious birds and penguins, whilst in the swifts and humming birds it is characterised by its thickness, strength, and the development of its muscular processes. In the cursores it is short and attenuated, resembling the corresponding part in the paddle of the turtle. Its head is oblong transversely, and enlarged by two lateral crests, under one of which are to be found the air passages leading into the bone. The lower extremity of the humerus is formed after the manner of a hinge, consisting of an internal spherical portion to articulate with the ulna, and an external oblong portion for the radius.

The *radius* and *ulna* are straight and slender bones, enlarged at their extremities, and placed one in front of the other, so as scarcely to admit of any pronation or supination. In the penguins the bones of the fore-arm are flattened, and articulated with the anterior edge, and not the extremity of the humerus.

The *carpus* is composed of two bones only, and so wedged in between the metacarpus and fore-arm, as to limit the motions of the hand to adduction and abduction.

The *metacarpus* is chiefly formed of two bones, a small ulnar one, which supports a single phalanx, and a large radial one, which sustains two phalanges. A small rudimental bone is usually anchylosed to the outer side of the proximal extremity of the radial metacarpal bone.

Lower extremity.—The pelvic bones, like those of the shoulder, are three in number: the ilium represents the scapula, the ishium

the clavicle, and the pubis the coracoid bone. Unlike the shoulder, however, these bones are always anchylosed into one piece on either side, and with one exception, never join in the mesial line; this single exception is afforded by the ostrich, in which the pubic bones complete the pelvic circle by anchylosing at their inferior extremities. The vulture *cinereus*, and some acquatic birds, form the nearest approach to this last condition. In them the pubic bones are often surmounted by a cartilaginous appendix at their anterior extremity.

The *ilium* is the only bone of the pelvis that comes in contact with the spine; it is elongated in form, narrow in the centre, and expanded at its extremities. This bone is anchylosed with the sacrum, the ischium, and the spinous and transverse processes of one or two dorsal vertebræ.

The *ischium* lies parallel with the ilium; it is a small oblong bone, not presenting any peculiarity.

The *pubis* unites with the ischium in a two fold manner in the humming bird and some others, so as to form two foramina obturatoria, while in others, as the stork, it is only united to it at the cotyloid foramen. This cavity is always incomplete at its internal part, where it is closed by some fibrous bands.

The *femur* is short, and slightly convex anteriorly; its head is hemispherical, and joined to the shaft at a right angle, without the intervention of a neck. There is but one trochanter; it is of a large size, continuous with the external part of the shaft, and generally rises above the level of the head. The lower extremity of this bone presents two condyles, the inner one for the tibia, the outer one, which is longer and larger, rests on the tibia and fibula; it is convex from behind forwards, and terminates in a groove in both these directions.

The *tibia* is the principal bone of the leg, the fibula ending in a point inferiorly, and achylosed to the tibia for a considerable extent. The lower extremity of the tibia forms a transverse trochlea, above which there is a deep groove or foramen, to transmit the tendon of the extensor digitorum communis. The upper and anterior part of the tibia gives rise to a long pointed process, which ascends in the shape of an olecranon in front of the joint, being also anterior to the patella.

The *tarsus* can only be recognised as a distinct segment of the foot, when examined at an early period of the bird's existence; then only can be found a distinct astragalus of a flattened oval form, convex superiorly, and concave below, where it meets the three bones of the metatarsus partially separated. A rudiment of os calcis may also be found in the extensor tendons. In the penguins, the three *metatarsal* bones are only anchylosed at their extremities; but in other birds, faint grooves alone indicate their existence. The remote extremity of the metatarsus presents three convex facets to articulate with the *toes*. These last are subject to great variety as to number, being reduced to two in the ostrich, and increased to

five in the gallinaceæ. The phalanges bear no proportion to the size or number of the toes, being found to vary from one up to five.

RECAPITULATION.

1. There is more uniformity observed in the skeleton of birds, than in any other of the vertebrated classes.
2. The bones are white, thin, and brittle; in early life, filled with a thin serous oil, which is subsequently removed to be replaced by atmospheric air, especially in those of the high-flying kind.
3. The bones are early and rapidly ossified, particularly those of the head, thorax, and pelvis. This ossification also affects the tendons of the muscles of the leg, sclerotic tunic of the eye, inferior larynx, and the rings of the trachea.
4. Arms adapted solely for flight; legs for support.
5. Head and neck long, for the purposes of prehension.
6. The dorsal and sacral portions of the spine the most fixed.
7. Cervical vertebræ more numerous than in the mammalia; occasionally, three times the number.

MAMMALIA.

The number of vertebræ contained in the *spine*, is very variable; but the human type is by far the most generally predominant. In the cetaceæ there is no distinction between lumbar, sacral, and caudal vertebræ; and in the porpesse, there are sixty-six posterior to the dorsal: these mammalia, however, have no pelvis. The cervical vertebræ are uniformly seven throughout this class, notwithstanding Cuvier imagined he had found a solitary exception in the neck of the aï, bradypus tridactylus; but it has been well ascertained since, that what he conceived to be the two last cervical vertebræ of this animal, have two rudimental ribs attached to them. When we are reminded of the localities and habits of the sloth, hanging from the branches of trees, and passing from bough to bough, aided by the current winds, it becomes obvious why such a provision should exist, of modifying the two superior dorsal vertebræ, and of consigning to them the offices of cervical, rather than infringe on a law which at present seems without an exception.

The dorsal vertebræ range from twenty-three, as seen in the unau, bradypus didactylus, to twelve, as presented by man, mice, bats, rabbits, hares, and several apes. In the megatherium there are sixteen, in the horse eighteen, and in the elephant twenty. The lumbar vertebræ are generally seven; they vary, however, there being two in the two-toed ant-eater, and nine in the lori. The sacral vertebræ are seven in the mole; in the vampyre bat, opossum, and some apes, there is but a single sacral vertebra, the usual number being three. The caudal vertebræ are four in man and the ourang-outang; forty in the two-toed ant-eater; and in the vampire bat they are altogether absent.

In most animals, it has been said, that the head and neck together equal in length the fore-feet, except where the latter are used as hands, as in the apes and rodentia. The neck attains its greatest length in the genus camelus, and is shortest in the order cetacea, owing to the consolidation of the vertebræ. According to the statement of Gore, the number of cervical vertebræ in certain of the cetacea, as the balæna, manatee, and dugong, amounts only to six. In the rodentia, and most long necked animals, the spinous processes are almost wanting. The atlas, in the carnivora, ruminantia, solipida, pachydermata, &c., is distinguished by its length, and by its large aliform transverse processes. The free motion and beautiful arch observed in the necks of some horses, camels, &c., is explained by the bodies of the cervical vertebræ having a perfect articular head on their upper surface, and a corresponding depression on their lower, similar to what we observe in the necks of serpents, with this difference, that the surfaces are reversed. The ruminantia, rhinoceros, elephant, &c., are remarkable for the great length of the spinous processes of the dorsal vertebræ. Bats have scarcely any spinous processes; and, with the exception of the second dorsal, they are short in the rodentia. In the lumbar vertebræ, the form of the transverse processes is very variable—almost absent in bats, very strong in the ruminantia, rodentia, and carnivora. The megatherium possesses long spinous processes. In the sloth, the length, breadth, and consolidation of the sacral vertebræ remind us of the sacrum of birds. The few first only of the caudal vertebræ in mammalia contain a prolongation of the vertebral canal. Animals with long movable tails, as the two-toed ant-eater, have oblong triangular processes on the under surface of the caudal vertebræ, as in the crocodile. The connection of the vertebræ is almost always by means of interarticular cartilage, as in man, and consists of concentric rings, most evident in the whale. In the pig and rabbit the interarticular cavities are filled with an albuminous fluid, as in fishes.

Ribs.—Man has seven true and five false ribs; the balæna whale, one true and eleven false; in the unau, or two-toed sloth, there are twenty-three pairs, of which eleven are false; in the horse eighteen, and eight of them false; in wolves, cats, and some apes, there are thirteen pairs, four of which are false; in the guinea pig, armadillo, and porpoise, there are thirteen, of which seven are false; in the manatee, of sixteen pairs, but two are true; in the dugong but three out of eighteen; and in the ornithorhynchus but six out of seventeen. The breadth of the ribs is greater in the ruminantia, pachydemata, in the manatee, and especially in the two-toed ant-eater, than in other mammalia. The connection of the ribs with the sternum is in general effected by cartilage; but in the cetacea, ant-eaters, dasypus, bradypus manis, ornithorhynchus, echidna, and frequently in bats, the union is completely bony.

Sternum.—This bone, though essentially the same as in the human subject, is somewhat modified in form by the shape of the

chest. In ungulated animals, where there are no clavicles, the sternum is compressed laterally, and projects in the centre like a ship's keel. The superior piece of the sternum is very considerable in the mole, where it forms a distinct bone. It is proportionably small in the bat, seal, horse, rhinoceros. In the cetacea it is short and large, being composed of five pieces in the dugong, and three in the dolphin, the porposse, and the platanist. In the bat and ornithorhynchus, the upper part of the sternum is T-shaped, the transverse process being for the articulation of the clavicle.

The figure of the *thorax* in most apes, bats, and the greater number of the rodentia, and, in fact, of the class mammalia, having clavicles, agrees with that of the human subject. In ungulated animals, on the contrary, where there are no clavicles, the thorax is laterally compressed and elongated.

The whole arrangement of the thorax proclaims man to be destined to move in the erect attitude: he is the *only* animal in which its transverse exceeds the antero-posterior diameter; even in the chimpansè, which approaches nearest to him, the latter exceeds the former measurement, reminding us of the form of this cavity in the very young subject. Its great lateral width and inconsiderable depth from sternum to spine, throw the arms apart, and increase their sphere of motion. The reverse characters, together with the absence of clavicles in quadrupeds, allow the fore legs to approximate, to fall perpendicularly under the front of the body, and support it with ease and security.

Head.—We shall cease to wonder at the striking differences observed in the construction of this part of the skeleton, when we consider that it forms the receptacle for the brain, most of the external senses, the masticatory apparatus, &c. Man combines by far the largest cranium with the smallest face; and animals deviate from these relations in proportion as they increase in stupidity and ferocity. In man, the area of the section of the cranium is nearly four times as large as that of the face; three times as large in the ourang-outang; twice as large in the sapajous; and they are nearly equal in the baboons and carnivora. In the hare and marmot, the face exceeds the cranium by one third; in the porcupine and ruminants, by one half. The face is three times as large as the cranium in the hippopotamus, and four times as large in the horse.

The superior maxillary bones of the human subject are united to each other, and contain all the upper teeth; in some other mammalia, however, they are separated by a coniform bone, which contains the incisor teeth, and hence named os insicivum; but it exists where there are no incisor teeth, as in the kerotophara, the elephant, and the two-toed rhinoceros of Africa, and even where there are no teeth at all, as in the ant-eater and some of the cetaceans, for which reason Blumenbach calls it os intermaxillare. In some it is a single bone, in others double; it is absent from the chimpansè, though present in the ourang-outang. The former of

these animals possesses supercilliary ridges, which are wanting in the ourang.

The head of the ourang, viewed in front, is pear-shaped, expanding from the chin upwards, the cranium being much the larger end. The frontal sinuses are very large in the dog, wolf, porcupine, sloth, sheep, bull, pig, horse, and especially in the elephant; they are small in bats, rats, squirrels, ant-eaters, the hippopotamus, rhinoceros, &c. In cats, martens, and bears, the parietal bones give off from their inner and posterior edge a process of bone which projects into the cavity of the skull, and forms a perfect bony tentorium cerebelli. In the dog and horse, similar processes arise from the petrous portion of the temporal bones.

The lower jaw is subject to many varieties in the mammalia. In the whale it resembles two enormous ribs, united at the point, without any trace of ascending rami or coronoid processes. The articular head here, as well as in the porpoise, is directed backwards, and is attached to the skull by means of strong cellular tissue, filled with oil.

In the hare, rabbit, and guinea-pig, of the order rodentia, the coronoid process is very small; in others, as squirrels and rats, it is pretty large. The condyloid, or articular process, is compressed latterally, directed from behind forwards, and larger in front than behind.

In the carnivora, the articular head is directed transversely, and so closely adapted to the glenoid cavity of the temporal bone that the jaw retains its situation after the destruction of the ligaments. This is well seen in the marten and sea-otter. In the ruminants the condyle is very flat, to admit of the lateral motion necessary during the process of rumination. In the carnivora, rodentia, and ruminantia, the two halves of the lower jaw are never firmly united—in this particular affording us an instance of the permanence of a condition in other mammalia, which in man is peculiar to the earliest periods of life.

Swine have two small bones placed at the aterior openings of the nares for the support of the snout. In fine, it is to be remarked that the crania of all the quadrumana, together with the other mammalia, are distinguished by the comparative size, great length and projection of the jaws.

Anterior extremity.—This extremity in the lower animals corresponds to the superior of the human subject, and contains all the elements of it, modified according to the habits of the animal. Sometimes connected to the trunk by means of muscle only, as in the cetacea, pachydermata, ruminantia, and solipeda; in other instances by ligament and muscle, as seen in the insectivora.

Clavicle.—The importance of this bone, in the motions of the upper or anterior extremity, may be well estimated by the fact of its being present in those animals only whose habits of life require free and varied motions of the shoulder. Thus in the quadrumana it is strong and curved, as in the human subject. The bat, hedge-

hog, and mole, among the insectivora, afford examples of clavicle in its highest degree of development. It is very perfect in the rodentia, as the squirrel, beaver, rabbit, rat, &c. Among the edentata, those animals only whose habits are fossorial possess clavicle, as the ant-eater, the dasypus, and the gigantic megatherium; in the last named animal it presents the peculiarity of being articulated with the first rib instead of the sternum.

Where the anterior extremity is employed merely for the purpose of progression, we find no clavicle, as in the pachydermata, ruminantia, cetacea, and solipeda. In the carnivora, where there is a slight increase in the range of motion of the anterior extremities, the clavicle exists in a rudimental form, and its development is in proportion to the motion enjoyed; hence it is small and short in the cat, the bear, and the dog; in these animals it has no attachment to the sternum or scapula, but lies loose among the muscles.

Scapula.—This bone forms an essential element of the thoracic extremity, and exists wherever the latter is fully developed, but greatly modified, according to the uses to which the extremity is applied. The cetacea, in general, have a large scapula of a triangular form; the pachydermata, ruminantia, and solipeda, have a long narrow scapula placed perpendicularly on the anterior and lateral part of the chest. In the carnivora and rodentia, where strength and freedom of motion are required, the scapulæ are placed obliquely over the ribs; and it is interesting to observe how the obliquity of the glenoid cavity varies with the motions required. This fact has not escaped the observation of the horse-jockey, who is well aware that the upright shoulder is the mark of a stumbling horse.

Humerus.—When the fore-arm and hand are used for seizing objects, as in apes, many rodentia and carnivora, or for flying, as in the bat, the humerus is formed essentially in accordance with the human type. On the contrary, when the anterior part of the member is but slightly developed, as in the cetacea, the bone is short and thick; and in the whalebone whale, it is nearly as broad as it is long. In the mole it is short, thick, and strong; its tuberosities greatly developed, and its upper extremity presents two articulating surfaces, one for the scapula, and the other for the clavicle. This large size of the bone prevails in all the other fossorial animals, as the mighty megatherium, the pangolins, beavers, ant-eaters, and monotremata. The humerus of the lion is remarkable for being perforated by the brachial artery and nerve, in order to avoid being crushed by the huge and powerful mass of muscles exhibited in this part of the economy of the king of beasts.

Fore-arm.—The radius and ulna are very short in the cetaceans, and in most of them consolidated together at both extremities. In the cheiroptera they are long, slender, and firmly united, to accord with their mode of progression by flight; in some the olecranon is wholly absent, and in others, as the vampyre, it exists in the form of a patella. The ruminants and solipeds have these bones con-

solidated into one. The rodentia, many carnivora, pachydermata, insectivora, and edentata, the bones are distinct throughout, but admit of no motion. The sloth, however, among the edentata, enjoys great freedom of pronation and supination; here the bones are long, arched, and widely separated in the centre.

Carpus.—The bones composing this part of the extremity are usually disposed in two rows, as in man, though the number almost invariably differs from that model. The following is Cuvier's statement of their number:—In man and the elephant, 8; in apes, the hare, and the mole, 9: in the solipeda, carnivora and several rodentia, 7; in the ruminantia from 6 to 7; in the edentata, 6; and in cetacea from 4 to 7. In apes, carnivora, and several of the ungulata, the pisciform bone is very large, and by affording attachment to the flexor muscles of the hand, performs the office of os calcis in the foot. The simiæ, in general, have nine bones in the carpus—another distinction between their hand and that of man. In the most anthropo-morphous of them, the chimpansè and the ourang-outang, the ninth is a sesamoid bone in the tendon of the abductor pollicis longus.

The *metacarpal bones* in the whale are five in number and flattened in the form of *phalanges.* These last are, two in the thumb, three in the little finger, four in the index and ring fingers, and five in the middle, collectively forming a short but strong paddle. The shovel-shaped hand of the mole consists of five fingers, each having a metacarpal bone and three phalanges. In the bat the thumb is short, and not included within the flying membrane, The metacarpal bones are long, slender, and cylindrical; the distal phalanx is hooked, and sustains a nail by which the animal suspends itself. The simiæ have these parts constructed as in man, except the thumb, which is small, and extends only to the metacarpo-phalangeal articulation. In bears and badgers the five fingers are of equal length, and parallel to each other. In the endentata several of the fingers disappear; for instance in the two-toed ant-eater, the thumb, index, and little fingers, are merely rudimentary; the middle finger, however, is proportionally developed.

Among the ungulata the hand is still more diversified; the elephant, for example has five fingers all united into one mass within the skin. The pig almost wants the thumb; he, however, has four perfect fingers, but walks only on two. The ruminantia have but two fingers, each metacarpal bone supporting three phalanges. In the solipeda there is but a single finger; for instance, in the horse the carpus corresponds to the knee; the metacarpal bones are consolidated into one, cannon bone, behind which there are two small, splint bones, commencing broad at the knee, and terminating in a pointed manner behind the lower third of the cannon bone. Here we meet with three phalanges, the first called pastern, the second coronet, and the third coffin bone.

Pelvis.—It has been truly asserted that in the human skeleton alone, a *true pelvis* is to be found. This arises from the form and

manner of connection of the bones entering into the formation of this cavity. The chimpansè and elephant afford us the nearest approach to the human formation, even here the ilia are narrow and elongated; and the sacrum and coccyx are flat, contracted, and continued in a direct line with the spine. Next in the order of development may be ranked the rhinoceros, the ox, the horse, the carnivora and the rodentia. In ant-eaters, moles, and shrews, the symphysis pubis remains open; and in the two latter genera the pelvis is so small that the pelvic viscera are placed without it. The megatherium and sloth, however, have pelvis of large dimensions. Some of the edentata, as the dasypus, have the ilia joined to the sacrum. In others, as the sloth and some of the ant-eaters, the ischium is connected with the sacrum, forming an ischiatic foramen, instead of a notch. The cetacea present but slight rudiments of a pelvis in the form of two small bones united to each other and to one of the vertebræ by cartilage. Finally the marsupial animals present a small, elongated pelvis, especially remarkable for the presence of two particular bones not found in any other mammiferous animal even in a rudimental state, and named *ossa marcipialia.* These bones are attached, but not articulated, to the anterior part of the pubis, near the symphysis; each is about three inches long in the kangaroo, flat, with anterior thin, and a posterior thick edge. The bone is triangular in form, the broad end being at the pubis, while the narrow has attached to it the abdominal muscles. The use of these bones is to support the *marsupium*, or abdominal pouch, in which the mammary apparatus is lodged, and the young animal nurtured.

The *posterior* or *abdominal extremity* is altogether absent in the cetacea. In the other mammalia inhabiting the sea, the seal, for instance, the several elements of the posterior extremity, even the toe-nails, are distinctly recognisable, but consolidated by a membranous web into a kind of caudal fin.

The *femur* in the lower mammalia is short and straight; the neck is either absent or but little developed, the head being placed vertically over the shaft. The trochanters and linea aspera are badly marked. This bone is shorter than the tibia, the converse to what obtains in man. In the megatherium its thickness equals half its length. The trochlea is a deeper and the transverse diameter of the condyles less than in man.

The *patella* is usually present in the mammalia; best developed in the pachyderms, solipeds, and monotrems; least so in the carnivora and quadrumana; and wholly absent in the marsupiata and cheiroptera.

Tibia and *Fibula.*—Throughout the mammalia these bones coincide pretty nearly with those of the fore-arm. As in man, the tibia forms the chief bone of the leg. The fibula is analogous to the ulna, and is found only in a rudimentary state in the solipeds and ruminants, as the latter bone was in these animals. In the solipeds, the fibula is applied to nearly the upper half of the outer surface of the tibia, being pretty large above, and ending in a fine

point below. Ruminants, on the contrary have the fibula better developed inferiorly where it forms the external malleolus and extends but a short way up the leg. Pachyderms, and all the unguiculata, possess a fibula well developed; and in sloths its lower extremity ends in a conical point, which enters a corresponding cavity in the astragalus. In the rodentia, and insectivora, particularly the mole, the tibia and fibula are united through their inferior half. Carnivora have these bones fully developed and detached: this is well seen in the phocidæ and felinæ. In the dog they are united posteriorly.

Tarsus.—The bones composing this part of the foot for the greater part resemble those of man. The cheiroptera present a remarkable peculiarity in the formation of a long slender bone, extending from the back of the os calcis half way to the tail, and enclosed within the flying membrane. Cuvier and Meckel supposed it to be a portion of the os calcis, whilst Daubeton conceived it to be a distinct bone. On the inner side of the tarsus of the mole, a sickle-like process of bone is found, similar to that observed on the carpus. The *metatarsus* and *toes* in ruminants and solipeds are disposed pretty nearly as in the anterior extremities. The rodentia and carnivora have usually five toes, the great one being often shortened, or as in cats, dogs, and hares, altogether absent. The quadrumana and marsupiales have the great toe separated from the rest, bearing the same relation to the foot as the thumb to the hand.

Although the disproportion in the respective size and length of the upper and lower extremities of the human subject, indicate the different functions they are designed to execute, yet they present many *similarities* throughout their divisions, the construction of their articulations, and the number and form of their bones. The arm, fore-arm, and hand, for instance, resemble the thigh, leg, and foot; the os innominatum may be compared to the scapula; the hip, knee, and ankle, to the shoulder, elbow, and wrist: and the carpus, metacarpus, and fingers, to the tarsus, metatarsus, and toes. *Contrast.*—A line falling perpendicularly from the shoulder in the erect attitude, would pass behind the hip. The upper extremities diverge below, whilst the inferior converge. The deep acetabulum, and the strong tight capsule of the hip, may be well contrasted with the shallow glenoid cavity, and weak, loose capsule of the shoulder. The lower extremities are as long as the head and trunk together, being only equaled in this respect by the kangaroo and jerboa.

The great length of the shaft and neck of the femur, its perpendicularity with the spine, and the depth of its internal condyle, are characters peculiar to man: in the fore-arm every thing conspires to procure freedom of motion; in the leg, strength and security are the objects aimed at. The hand is articulated on a line with the fore-arm, and enjoys free and varied motions; the leg joins the foot at a right angle, and moves chiefly in the angular direction; the entire surface of the tarsus, metatarsus, and toes, rests on the ground: the two latter circumstances are *exclusively* confined to

the *human subject.* The parts composing the hand and foot are disposed inversely as regards their development and importance. The solid part of the hand is small, weak, and but slightly developed; that of the foot is large, firm, and ossified at an earlier period of life. The fingers are long, slender, and mobile; the toes are short, thick, and enjoy only a limited share of motion. But the distinguishing characteristic of the human hand is due to the strength, situation, and development of the thumb, which is opposable to the fingers, and rendered useful in the thousand offices which it has been designed to execute.

Man is distinguished from all other animals by the great size of the cranium over that of the face. One method of expressing these relative proportions, is by the course of the facial line, and the number of degrees in the facial angle. A line drawn from the greatest prominence of the forehead to that of the upper maxillary bone, in the erect attitude, describes the direction of the face, and is called the *facial line;* a second line, perfectly horizontal, drawn backwards from beneath the basis of the nostrils, forms with the other what is termed the *facial angle*, and gives the measure of the relative prominence of the jaws and forehead. In the adult human subject the facial angle varies from 65° to 85°; in children it reaches 90°; a sufficient proof of its inadequacy as a standard for the measurement of intellect. The situation of the foramen magnum, and occipital condyles, being but little posterior to the centre of gravity, are also distinctive characters of man. A line drawn forwards parallel to the plane of the foramen magnum, will come out just under the orbits. In the ourang-outang this line would pass below the level of the lower jaw, and in most other animals the foraman magnum is placed on the back of the head, its plane being nearly vertical. The great weight of the human head, the absence of ligamentum nuchæ, and of the rete mirabile, or some analogous provision for moderating the influx of blood to the brain, coupled with other facts hereafter to be mentioned, incontestably prove that man was intended for the erect attitude, and that he is quite unfit to move on all-fours, as some modern authors would have it.

Nature has clad in defensive mail the armed rhinoceros, provided the lion and the tiger with weapons of defence, clothed the sheep in wool, and the bear in fur; every animal she has bountifully provided in all that was necessary for its subsistence, and adapted to its destined mode of existence. Man alone she has abandoned, weak, naked, and defenceless, unarmed in the midst of dangers, and uncovered to the winds of heaven. But she has bestowed on him gifts far more than equivalent to all that was denied: she has given him an illimitable capacity for improvement; she has endowed him with terrestrial ubiquity, or a capability of inhabiting every part of the known world: and above all, she has conferred on him intellect and inventive genius, which have raised him to a measureless superiority over the rest of created beings. By means of these endowments he has made most animals subservient to his purposes,

and obedient to his commands; and such as their native ferocity renders incapable of utility, or dangerous to his repose, he has banished to the "howling wilderness." In fine, the surface of the earth attests his industry and intelligence, and nature herself is delighted to obey him.

RECAPITULATION.—*Characters Peculiar to Man.*

Biped; bimanous; erect attitude; great proportion in the size of the cranium over that of the face; development of brain; direction of facial line; articulation of the head with the spine; rational; endowed with speech; prominent chin, and teeth of peculiar characters; absence of ligamentum nuchæ and intermaxillary bone; great transverse measurement of the chest; curved spine, sacrum, and coccyx; large pelvis; short arms; long, powerful thumb, possessing separate flexors; length and direction of the neck of the femur; depth of internal condyle; the whole flat of the foot resting on the ground, and the leg joining it at a right angle. Man is also remarkable for the smoothness of his skin, and the slowness of his growth.

The following are Camper's measurements of an ourang-outang, compared with those of man:

	MAN.	OURANG.
Whole length of the body from vertex to heel,	71 inches.	Less than 30 inches.
Superior extremity,	32 "	" 24½ "
Inferior do.	39 "	" 16 "
Humerus,	13 "	" 8½ "
Ulna,	9⅞ "	" 9 "
Hand,	8¼ "	" 7 "
Thumb,	4¼ "	" 1¼ "
Middle finger,	4¼ "	" 3 "
Femur,	20 "	" 7 "
Tibia,	16¾ "	" 7 "
Foot,	10½ "	" 7½ "
Middle toe,	2¼ "	" 2¼ "

FOSSIL BONES OF ANIMALS.

It is the undivided opinion of geologists, that there has been a regular succession of deposits in the earth, and that the remains of different animals (many of them long since extinct) are to be found in the several strata. In the deeper strata, the remains of animals low in the scale of organisation are to be met with; in higher strata, oviparous animals of large size and complex structure are discovered; above these are found mammalia; and still nearer to the surface, the bones of the megatherium, mastodon, rhinoceros, elephant, &c.; and it is now the prevalent opinion that man was created last of all.

Some bones are found with their animal ingredients remaining others are fossilised. The phosphate of lime loses its phosphoric acid, and the earth remains incorruptible, while the soft animal matter decomposes and dissipates. The bone in this condition may become fossilised; silicious earth, or lime combined with iron, may pass, by infiltration, into the interstices of the original earthy matter, and in this state it is permanent as the solid rock.

There is preserved in the Royal Museum of Madrid, a skeleton of the enormous megatherium of Cuvier. It is supposed that the animal was seven feet in height; for its femur is three times the diameter, and its pelvis twice the breadth of that of an elephant.

CHAPTER IV.

LIGAMENTS.

In the lowest grades of animal beings, cartilages, synovial membranes, capsular or accessary ligaments, scarcely exist at the joints. We here find the movable points formed of a tough connecting material, which, by its elasticity, admits of the limited motions required.

No ligamentary apparatus appears in the soft, gelatinous animalcules; but the silicious and calcareous spicula of the poripherous radiata are supported by a tough, elastic species of cellular tissue. The plates composing the shells of the echinida are united by sutures, and the enarthroidal joints of the spine by capsules, and often by a ligamentum teres, as in the cidaris. In the larger crustacea and coleopterous insects portions of the skeleton are locked into each other, where they move securely, but to a limited extent, in the angular direction without ligaments. The shells of the conchifera are united by their locking teeth, and by a strong, tough ligament, which, by its elasticity, constantly tends to the separation of the bivalves.

In the soft, flexible skeletons of the cartilaginous fishes, the ligaments are few, and confined to the organs for mastication and progressive motion. But in the osseous fishes the ligaments of the spine are white, fibrous, dense, and highly elastic; and here, for the first time, we meet the contiguous ends of bones incrusted with cartilage. In the amphibia, and in the reptiles, the bodies of the vertebræ are united by enarthroses, furnished with strong fibrous capsules and synovial secretion. Here we have external fibrous bands, interspinous ligaments, and occasionally loose cartilages in the joints. The capsular ligaments of birds are thin and strong: their cartilages of incrustation are also thin, but their joints are freely supplied with synovia and their hip joint furnished with a strong ligamentum teres.

In the mammalia, thick fibro-cartilages appear interposed between the bodies of the vertebræ, and in the carnassier and climbing mammalia, the articular processes are furnished with well developed synovial capsules. The tails of many quadrupeds enjoy full motion from their coccygeal vertebræ being united by synovial capsules. The anterior and posterior common ligaments of the spine are powerfully strong and highly elastic along the pliant columns of the cetacea. In the large and heavy-headed herbivorous quadrupeds, the ligamentous nuchæ is of great size and strength, extending from the occipital protuberance along the cervical and dorsal spines, and in many instances, to the coccygeal and iliac spines. The light-headed, and active muscular carnassier have this ligament short and small, and in the quadrumana and many of the rodentia scarcely a trace of it is to be found. The inter-articular cartilage of the lower jaw is met with, in this, but not in the preceding classes, the ligamentum teres is found in most of this class, but is said to be absent from the ourangs, the elephant, the rhinoceros, the hippopotamus, the kangaroo, the sloths, and the monotremata. The two toes of those ruminants, whose habits oblige them to make rapid and bounding movements, are secured by strong transverse ligaments passing between their phalanges.

CHAPTER V.

ON THE MUSCULAR SYSTEM IN THE INVERTEBRATA.

General observations.—In the higher orders of animals, there is a close relation, and a perfect mutual dependence between the osseous and the muscular systems; so much so, indeed, that the arrangement of one may be at once inferred by any one who possesses a sufficient acquaintance with the other. It is by means of this system that animals are enabled to move from place to place, to seize, masticate, and swallow their aliment, to circulate their fluids, to expel their excretions, to produce various sounds, and to accomplish an infinitude of other purposes. A system ordained to execute so many offices cannot fail to present some interesting peculiarities in the animal kingdom. In obedience to a law, often alluded to, we find that the muscles of the highest classes of red-blooded animals, during their development, pass through the soft, colourless, and gelatinous condition of those of the lowest species before they attain the characters peculiar to them in their highest state of development.

Radiata.—No muscular fibres have been hitherto found in the polygastric animalcules. Their rapid motions through the fluids which they inhabit appear to be accomplished by means of the vibrations of minute cilia (which are analogous to the villi on the mucous surface of a small intestine) growing from the outer surface of their

bodies; the cilia which in these animalcules, serve the double purpose of locomotive and respiratory organs, have been observed in every class of animals, even the mammalia.

In the zoophytes, the soft, fleshy mass, which we have seen secrete the solid matter of the skeleton, possesses distinct, but languid irritability: no part of these animals is, however, so irritable and contractile as their prehensile sacs or polypi. It is not till we arrive at the stellerida and asterias that distinct muscular fibres have been satisfactorily demonstrated; and in the echinida strong adductor and abductor muscles are seen attached to, and moving the jaws of several species.

Articulata.—Seeing that these animals possess an extensive surface for respiration, and a highly developed nervous system, we are prepared to meet with considerable muscular energy. Accordingly, in the nematoid entozoa, strong muscular fibres are seen taking different directions: the rotiferous or wheel-animals, are also remarkable for the development of the muscular apparatus provided for the movements of their jaws, and long vibratile cilia. The common earth worm has distinct muscles appropriated to the movements of its conical pointed feet, and its anus is well furnished with levator and sphincter muscles. The insects and the air-breathing arachnida possess a well marked muscular system; but of all the branchiated invertebrata, the crustacea possess the largest proportion of muscle; this they require for the purpose of swimming, escaping from danger, &c. Although these animals are provided with external organs of mastication, the interior of their stomach is set with numerous teeth, and its exterior provided with a suitable arrangement of muscle.

Mollusca.—The muscular system presents much greater variety of form in this than in the articulate class. The tunicata possess a distinct muscular coat within their cartilaginous covering, by which they act on their entire body, and empty their thoracic cavity; the orifice of which, as well as the anus, is provided with sphinctorial muscles. The foot of the conchifera, by which they swim, creep, burrow, or attach themselves, is hollow, and composed almost entirely of muscular fibres, taking different directions. This foot occasionally admits the water into its interior, and is absent from the oyster and others where the shell is permanently fixed. In the gasteropoda, the foot is the largest muscle in the body, and in trachelipodous gasteropods or those residing in turbinated shells, its fibres are traceable up to the neck, and backwards to be attached to the shell. The predaceous gasteropods possess a powerful muscular proboscis provided with a fleshy tongue, armed with sharp conical teeth, as seen in the common whelk, (*buccinum undatum.*) In the chephalopoda and pteropoda, muscular fins are attached to the side of the trunk for progressive motion. And in the naked cephalopods, a thin panniculus carnosus with interlacing fibres, is spread all over the body, beneath the coloured skin of the mantle. The octopus is destitute of any lateral fins, but is provided with a

muscular membrane extended between the bases of its feet, by which it is enabled to swim; but what is curious about it is, that it swims backwards by impelling the water forwards.

CHAPTER VI.

ON THE MUSCULAR SYSTEM IN THE VERTEBRATA.

PISCES.

In all the vertebrata the soft parts are uniformly placed external to the hard resisting textures: in them the muscles of animal life are generally of a red colour, and connected to bone by at least one extremity, through means of tendinous or fibrous structure. In *fishes*, the muscular fibres are soft, gelatinous, and colourless as in the invertebrata, and the embryos of the higher vertebrated classes. In the salmon, however, they are of a higher red, especially about the head; and in the lamprey they are blackish gray. The arrangement of the muscles in the osseous fishes is such, that a large mass extends from head to tail on each side, divided by fibrous bands into numerous strata. The active movements of fishes are not subject to much variety; their ascent or descent is effected by the compression or expansion of the air-bladder, and by their pectoral fins, whilst they are impelled forwards by the lateral motion of the tail opposed by the resistance of the water. When the swimming bladder is absent, as in the sole genus, or very small, as in the cobitis fossilis, the animal either remains at the bottom, or swims on one side by the vertical motions of the tail. The remora, lump-sucker, and others are provided with a muscular disk in the form of a sucker, by which they adhere to other fish or bodies moving through the water: so powerful is the muscular tail of the salmon, that, aided by the great elasticity of its spine, it is able to mount over cataracts fifteen feet high. The shark is especially remarkable for speed, so much so, that according to a calculation of Sir E. Home, it would, if not compelled to rest, swim over the circumference of the globe in thirty weeks.

AMPHIBIA.

The proteus, siren, and the tadpoles of the higher anurous species, are moved through the water by the same kind of lateral motion of the spine and tail as in fishes. The great lateral muscles that accomplish these motions are still pale, bloodless, and feeble, and their connecting cellular tissue is soft, scanty, and colourless; the muscles are slightly connected to the skin, and present but little appearance of tendinous structure. So far the muscular system closely resembles that of fishes, but in the adult state

of the anurous species, it presents characters very remote from them, arising from their great extent of respiration, and their inhabiting a rarer medium. The oblique caudal muscles in the tadpole of the tailless tribe, become absorbed with the vertebræ to which they are attached, as the animal assumes its permanent form; but its change of habits is still provided for by the great development of the muscles of the posterior extremity, in fact they closely resemble those of the human leg; and hence the act of swimming in man is an accurate imitation of that of the frog. In this animal, the extensors are much stronger than the flexors of the leg, and those of the arm are but feebly developed.

REPTILIA.

The rarity of the medium through which the air-breathing reptiles move, at once declares an increased development of muscular energy in this class. In the progressive motion of *serpents*, their vertebral column forms several S-shaped lateral curves; is shortened, and again stretched forwards, whilst the posterior part of the body is fixed: this rapidly performed constitutes a leap or dart. The ribs being free at their distal extremities, admit of extensive motion, and are furnished with large intercostal muscles of various lengths, some passing from rib to rib, and others over one or more to have distant insertions. These muscles have small shining tendinous bands, by which a great number can be attached to a small space, and thus admit of great variety in the movements of the ribs, which are not only subservient to respiration, but to progressive motion in these animals. The muscles of the head are strong, and in the rattle-snake and others, a portion of the temporal extends forwards like a buccinator, to embrace the poison gland and force its secretion into the perforated fang.

The *saurian* reptiles possess members sometimes organised for progression on the surface, sometimes for climbing, sometimes for swimming, and occasionally for flying; hence their muscles are more numerous and complicated than in serpents. A rudiment of diaphragm may be perceived in the dragons and geckos; and in the prehensile tongue of the chameleon there resides a beautiful muscular apparatus ordained to govern its stealthy movements in obtaining his food, and as Sir C. Bell aptly describes it, he lies more still than the dead leaf, his skin is like the bark of the tree, and takes the hue of surrounding objects. Whilst other animals have excitement conforming to their rapid motions, the shriveled face of the chameleon hardly indicates life; the eyelids are scarcely parted; he protrudes his tongue with a motion so imperceptible towards the insect, that it is touched and caught more certainly than by the most lively action. In the chelonia, the muscles of the extremities together with those of the shoulders and pelvis are well marked, whilst those of the jaws, lips, and chest are almost wholly absent.

AVES.

A greater degree of uniformity pervades the muscular system of this than any other of the vertebrated classes, yet it will be found to present many peculiarities. From the rarity of the element they inhabit, as well as from their rapid and long continued movements through it, their muscles require a considerable degree of vital energy, hence they are red, vascular, dense, and irritable in the high flying and rapacious tribes, although pale, soft, and feeble in those of heavier and slower habits. The fleshy portions of the muscles are short and thick, whilst the tendons are long, slender, dense, and often ossified; their trunk being almost fixed, the muscles of the dorsal and lumbar regions are feeble and indistinct, those of the neck, on the contrary, are well developed in accordance with the perfect and varied motions of this part of the spine. The muscles of the abdomen are week and feeble, and the diaphragm so imperfect in the centre as to allow the heart to come in contact with the liver as in reptiles. Of all the muscles, none reach so great a degree of development as those of the anterior extremity, especially those attached to the humerus. Birds possess three pectoral muscles, an anterior, middle, and posterior: they are all attached to the sternum and the proximal extremity of the humerus. In birds of flight, the great pectoral often equals in weight all the other muscles of the body combined. The latissimus dorsi and deltoid are feebly developed, whilst the psoæ, obturator externus, and quadratus lumborum, are wholly absent. The muscles of the lower extremity are remarkable for their long, slender tendons, and especially for the beauty and perfection of the mechanism by which they support the bird when asleep on roost, without any muscular action. This is accomplished by the *gracilis*, which, arising from the pubis, descends along the inner side of the thigh, and ends in a strong tendon, which passes in front of the knee-joint, and subsequently over the projection of the heel to terminate by attaching itself to the outer origin of the flexor digitorum perforatus. From this disposition it results, that the more the joints are bent, the firmer the twig on which the bird rests, is grasped, and the heavier it sleeps, the more secure it is. Every one is familiar with the fact of birds generally sleeping on one leg, this is for the purpose of throwing the entire weight of their body on it, and so grasping the firmer, and in order to increase the effect by adding to the weight of the body, some birds are in the habit of never going to roost without grasping a stone, or some ponderous body in the other foot.

Flight, which is the most chracteristic mode of progression in birds, is effected by the animal springing into the air; or, where the legs are so short, and the wings so long that it cannot jump high enough to gain the requisite space for the expansion of the wing, it throws itself from some elevated point. The humerus is next

raised, and the fore-arm extended, a considerable extent of surface thereby gained; the entire member being then forcibly depressed, the resistance which it receives from the air, effects the elevation of the bird; velocity of flight depends upon the rapidity with which these strokes succeed each other. The eider-duck is supposed to fly 90 miles an hour; the hawk 150, and every one has heard of the falcon belonging to Henry IV. king of France, flying in one day from Fontainbleau to Malta, a distance of 1350 miles.

MAMMALIA.

Some of the animals composing this class are destined to move like fishes through a watery element, some to fly through the air like the feathered tribes, some to climb treess, some to dig and burrow in the earth, and others to walk upon its surface. Habits so diversified bespeak corresponding diversities of muscular arrangement. Many approximations to the human type present themselves on the one hand, and indisputable recurrences of simpler forms on the other. The fleshy portions of the muscles are generally large and plump, proportioned to the size of the body, or the massive bones of the skeleton. The respiration being here less extensive, and the circulation more slow, than in birds, the temperature is lower, the muscular fibre less dense, and the tendons less prone to undergo ossific changes.

The arrangement of the muscles in the cetacea nearly coincides with that in fishes, the latter moving horizontally, the former chiefly in a verticle direction. The muscles of the ribs, spine, pharynx, os hyoides, and exterior nares, are well developed, those of the pelvis and posterior extremities disappear with those parts, and the muscles of the anterior extremities are curtailed and simplified, least so, however, in the phytophagous cetacea. The large herbivorous quadrupeds require strong muscles to move their massive and heavy trunks, and the active and predatory habits of the carnivora demand a still greater development of this system. In the ruminantia, pachydermata, and those animals without clavicles, the anterior extremities are placed under the trunk, which is suspended between their long vertical scapulæ by the great *serrati* muscles, in many instances prodigiously developed. The buffalo, the bull, and others of the ruminants, with many of the pachyderms, have the muscles of the neck large and powerful to move their heavy heads, which are often armed with large teeth, tusks, a proboscis, or huge horns. The external muscles of the ear are greatly developed in many of the herbivorous quadrupeds, and the muscles of the nose in the hog tribe.

The *panniculus carnosus*, which is thin, and finely spread over the trunks of the pachydermata, is strong and fleshy in the soft skinned ruminantia, where it is attached to the humerus and to the femur. In the mammalia covered with spines, as the echidnia, the

hedge-hog, and the porcupine, and those covered with scales, as the manis and the armadillo, this muscle is important in erecting or moving these epidemic organs, and in coiling or uncoiling the body. In the mole, and those animals that dig the earth, the flexors of the arm, the pectoralis major, the latissimus dorsi, and the teres major, are of vast size. In the rodentia, the muscles are pale, and those of the jaws of great magnitude. The marsupiata have the panniculus carnosus extended over the pouch in such a manner as to support the young abortive-like fœtus, and force the mammary secretion into its mouth. The arrangement of the muscles approaches nearer to the human type in the quadrumana than in any others of the mammalia. In them the flexor muscles are strongly developed on all their extremities. The thumbs, have no long separate flexors, but receive tendons from the flexors of other fingers. The plantaris muscle, which is very fleshy in monkeys, instead of terminating, as it does in man, by insertion in the os calcis, passes over that bone to be connected with the planter fascia and flexor perforatus. In other quadrupeds it passes over the os calcis to the sole of the foot, and supplies the place of the flexor digitorum brevis. The glutæus maximus, which is the largest muscle of the human body, is small and feeble in the simiæ and other animals, its chief use being to support the trunk upon the lower extremity, and thus assist in maintaining the erect attitude, and not, as the pious Spigelius imagined, to form a soft cushion for the body to rest on during divine cogitation.

Finally, the extensors of the knee, the flexors of the toes, and the other muscles forming the calf of the leg, are relatively larger in the human subject than in any other animal.

RECAPITULATION.

1. Muscular fibres have been satisfactorily shown to exist in the higher species of the radiata.
2. Muscle is found all through the articulate and molluscous classes, but better and more uniformly developed in the former.
3. The soft parts are uniformly placed external to the hard, in the vertebrated classes.
4. The muscles in fishes are generally soft and pale, as in the lower classes.
5. In the amphibia, the muscles present different characters in the tadpole and adult state.
6. Great variety in the reptiles, chiefly referable to their diversified habits.
7. The muscular system in birds is characterised by great uniformity throughout the class.
8. The muscles of the aquatic mammalia resemble those of fishes.
9. Serrati magni greatly developed in the quadrupeds not possessing clavicles.

10. Panniculus carnosus best marked in the echidna, the hedgehog, the porcupine, the manis, the tatu, the marsupiata, and the thin-skinned ruminants; less so in the pachydermata, and absent from some, as the hog. It is found in monkeys, but not in the chimpansé.

11. Lattismus dorsi, teres major, &c., are very powerful in the mole and ant-eaters.

12. The plantaris, which is rudimental in man, is large in monkeys and some quadrupeds.

13. Man is characterised by the magnitude of his buttocks, thighs, and calves.

CHAPTER VII.

ON THE NERVOUS SYSTEM IN THE INVERTEBRATA.

This system, when perfectly developed, consists of an internal or central, and an external or circumferential portion; to the latter belong the nerves and ganglions; to the former, the spinal cord, the medulla oblongata, the cerebellum, and the cerebrum. The nervous system presides over the movements of our muscles and the sensibility of our bodies; by it we are connected with surrounding objects, and an injury inflicted on any part of the body, at once declares the extent of its distribution, as well as the close relation that subsists between its several parts.

The nervous system has been detected in every division, although not in every class, of the animal kingdom: it commences its development at the circumference, and grows towards the centre, and its forms corresponds pretty closely with that of the body of the animal.

The nervous matter is extremely soft in the inferior grades of animals, as well as in the embryo of the higher classes; and its colour presents some variety, being bright red in the helix stagnalis; blackish red in the aplysiæ; and bright yellow in the common fresh water muscle. The nerves are composed of tubes filled with minute globules. The brain is also composed of globules, eight times smaller than those of the blood, larger and more numerous in the medullary, than in the cineritious substance, and in the former disposed in lines which gave it its fibrous character.

Cyclo-neura, Grant.—In the two first classes of this division, the *polygastrica* and the *porifera*, no nervous filaments have been detected, yet, from their active movements, their sensibility to the impression of light, and their consciousness of each others approach, it is but reasonable to infer the existence of a nervous system in them, though from its transparency or some other cause, it cannot be demonstrated. Both nerves and ganglions are found to exist in the three remaining classes of the radiata. Distinct nervous filaments surround the muscular foot of the actinia; and in the

acalephæ and echinodermata, fine nervous filaments and small white ganglions surround the entrance of the alimentary canal.

Diplo-neura, GRANT.—In this great division, the nervous system, presents the same extended form as the body, placed on the ventral surface of the alimentary canal, and except in the higher classes, not enclosed in an osseous sheath. Among the higher forms of the *entozoa*, as the ascaris, two fine nervous filaments extend along the median line of the abdomen, separating to embrace the œsophagus, and the vulva of the female. In the notommata clavulata of the *rotifera*, we find nine pairs of ganglions disposed along the course of the lateral columns. Scarcely a trace of nervous system can be perceived in the simple forms of the *annelida.* In the nereids, however, and many others of this class, the sympathetics become quite distinct; and numerous nerves are seen to pass off in the lateral direction. The common leech, which presents about eighty rings in the trunk of its body, has five and twenty ganglia placed along the abdomen, approximated at the two extremities of the column. In the most inferior of the diversified class of the crustaceans, the nervous system presents itself in the form of two slender abdominal filaments, in imitation of what we have seen in the preceding classes, and by a gradual development from the peripheral to the central parts, it arrives at that concentration of nervous ganglia around the œsophagus, which connects the highest of the articulate with the molluscous classes.

Cyclo-gangliata.—The greater number of the mollsuca being aquatic, their nerves present the same pale and soft characters observed in the other aquatic invertebrates; hence the difficulty of indicating their particular distributions. Here as in the radiata, the same tendency to accumulate nerves around the entrance to the alimentary canal prevails, but in this case more generally accompanied with ganglia. In the lowest classes of the division, as the tunicata and conchifera, the nervous chords are placed beneath the alimentary canal; in the two next classes *gasteropoda* and *pteropoda*, they are more in the vicinity of the stomach; and in the *cephalopoda*, which is the last and highest of the division, the nervous ganglia attain a more elevated position, they cease to embrace the œsophagus; and a distinct brain, as in the vertebrata, with numerous symmetrical ganglia along the abdomen take their place.

CHAPTER VIII.

NERVOUS SYSTEM IN THE VERTEBRATA.

PISCES.

We no longer find the nervous system perforated by the alimentary tract. On, the contrary, in all the succeeding classes, it

occupies a dorsal situation, and is protected by an osseous sheath. In the lowest orders of fishes, as the lamprey, and the gastrobranchus, we perceive a repetition of the two nervous columns extending along the back as observed in the worm. This simple condition resembles the embryo state of this system in the highest grades of the vertebrata, previous to the development of their extremities. With few exceptions the spinal chord extends the whole length of the vertebral column; whence, from the great number of vertebræ, it attains a very remarkable length. In some, however, as the lophius piscatorius, it is stated to be very short, forming a kind of cauda equina as in man. It usually terminates in a single thread, presenting several enlargements throughout its tract, which correspond very accurately with the number, magnitude, and situation of the extremities. For instance, when the anterior members are very large, as in rays and flying-fishes, the anterior enlargements are proportionally developed; and where a large caudal fin is to be supplied, the chord presents a sensible enlargement posteriorly where the nerves join it. The spinal marrow, here, as in the human fœtus, usually contains a canal of considerable size, and is distinguished by an anterior, a posterior, and two lateral grooves. From the latter, the nerves arise by two roots, the posterior or sensitive root having a ganglion on it, receives the anterior root immediately external to the canal.

The *brain* in fishes does not fill the cavity of the cranium, a considerable portion of it being occupied by the soft cellular tissue of the arachnoid. The medulla oblongata is of great length, lobed, and deeply grooved above by the calamus scriptorius.

In most fishes, the optic lobes are larger than the hemispheres, they are hollow and communicate freely with each other and with the fourth ventricle. The earlier they are examined the larger they are found to be; their development is proportionate to that of the optic nerves and eyes, and inversely to that of the cerebrum and cerebellum. The cerebral hemispheres are small in the osseous, apodal, and cyclostome fishes, and in the plagiostome species they are larger than the optic tubercles. In the osseous fishes they resemble the embryo condition of the human brain in being destitute of ventricles, and having no convolutions on the surface. In sharks and rays the hemispheres attain a large size, present irregularities on the surface, and ventricles in their interior. In front of the hemispheres are placed the olfactory tubercles, elongated transversely, and exceeding in magnitude the hemispheres themselves; subject, however, to considerable variations, regarding form, size, and situation.

The *cerebellum* is scarcely to be recognised in many of the cyclostome fishes. When present it appears as a transverse band, rising vertically in the osseous fishes, and forming a small vermiform median lobe, slightly laminated in the plagiostome fishes. In sharks and rays not only does this median lobe attain considerable magnitude, but small hemispheres are developed laterally, corresponding in size to that of the carpora restiformia. The pineal gland is found

in all fishes, lodged between the hemispheres and optic tubercles, but so small in the osseous tribes that its existence has been questioned. These several lobes are covered with a layer of cineritious substance, and closely invested by a delicate layer of pia mater; outside of which is the soft, gelatinous, cellular arachnoid tunic, and all are surrounded by an envelope of dura mater.

Nerves.—The olfactory nerves are white and fibrous; they are very large in the rays and sharks, and in many instances form a ganglion before their termination; as may be seen in the carp. The optic nerves are developed in proportion to the size of the optic tubercles and eyes; hence they are large in the carp, and slender in the eel. In the osseous fishes they generally cross without any intermingling of fibres; in the plagiostome fishes their fibres are blended at the commissure as in the mammalia; and in the skate, the right nerve goes through a fissure in the left. The third, fourth, and sixth nerves are developed in proportion to the size of the muscles they supply. The fifth nerve presents a greater size, and gives off more branches in this class than in any other of the vertebrata. The ophthalmic, superior, and inferior maxillary are distributed to the face, palate and lower jaw. In the rays, and many other fishes, it sends a branch to the ear, and in the torpedo, to the electrical organs. These latter are composed of a series of membranous cells occupied by a gelatino-albuminous substance, performing the office of a Leyden jar or electrical battery. They lie in the torpedo on the upper surface of the lateral fin. In the electric eel, on the posterior part of the abdomen; and in the silurus electricus they are situate between the muscles and skin over the entire body. In the last named fish the nerves appear to be derived from the pneumo-gastric. Both portions of the seventh pair are small and distributed without any peculiarity. The pneumo-gastric arises from the side of the medulla oblongata, behind the fifth pair; it forms a large ganglion below its origin, from which branches proceed to the branchiæ, the œsophagus, the stomach, and rudimentary lungs. This nerve gives off also a branch to the tongue analogous to the glosso-pharyngeal, and one to the lateral part of the body analogous to the spinal accessary, both of which are rudimental in fish. The ninth pair is wholly absent and its place supplied by a branch from the fifth. The distribution of the spinal nerves is very simple, and their development is always proportioned to the size of the fins; the sympathetic is very slender, and its ganglions small in fishes. It is most developed in the plagiostome chondropterygii, and least so in the cyclostome species; it receives filaments from the spinal nerves, and its meshes accompany the arterial trunks in their distribution on the digestive, respiratory, and generative organs.

AMPHIBIA.

The condition of the brain, the medulla oblongata, and the spinal chord are nearly the same in the perennibranchiate amphibia, and

in the larva state of those which undergo metamorphosis, as are observed in the osseous fishes. The lobed form of the medulla oblongata, the small cerebellum, the optic thalami, with the ventricles, and the diminutive extent of the hemispheres, all evince a degree of perfection not much above that noticed in fishes. The spinal chord is prolonged, small and tapering into numerous coccygeal vertebræ, and without sensible enlargements where the nerves are to come off to supply the future members. The metamorphosis of the caducibranchiate species, from the pisciform to the reptile state, develope an interesting series of phenomena. The hemispheres become enlarged, the cerebellum, which was scarcely visible, increases in size across the median line; as the limbs begin to appear, the spinal marow exhibits corresponding developments, but dwindles posteriorly as the coccygeal vertebræ disappear. So rapid are these changes in the nervous system of the frog, that we can appreciate them from day to day. The sympathetic system is more distinct in this class than in that of fishes.

REPTILIA.

In this class the cerebral hemispheres exceed in size the optic lobes, and contain a distinct ventricle. The cerebellum is remarkably small; and, in the sauria and chelonia, the spinal marrow presents an obvious enlargement, opposite the attachment of each nerve. The medulla oblongata is broad; the nerves are large, compared with the cerebral centres, but present no peculiarity of distribution. The plexuses of the sympathetic are here more closely connected with the arterial trunks, than in the preceding classes.

AVES.

The brain and spinal chord are in this class developed with more uniformity and perfection than in the cold-blooded reptilia; and bear a remarkable correspondence with the perfection of muscular energy which they possess. In a pigeon weighing 3360 grains, without the feathers, the brain weighed 37, and the spinal chord 11 grains=48.

The *spinal chord* extends from the foramen magnum to the coccygeal vertebræ, where it is greatly reduced in size, and expends itself in distributing a few nerves through the lateral foramina. The length of the chord is considerable, compared with the size of the brain; its shape is cylindrical; its anterior and posterior grooves are very distinct, as well as a minute canal extending through its whole length, arising from the union of the two halves of the chord: the dilatation of this canal in the pelvic region, is called "rhomboidal sinus." The spinal chord is chiefly composed of white matter, but contains a small quantity of gray, internally. Two enlargements occur on the chord, bearing a relative size to the development and powers of the extremities: in general the posterior enlargement is the greater, especially when the business

of progression devolves on the posterior members, as in struthious birds. The form of the chord is not altered in the alar enlargement, but simply increased by an accession of gray and white substances;—the lower one, on the contrary, not only receives additional matter, but the pillars separate, so that the fluid in the sinus is merely covered by pia mater.

The *brain* of the bird differs from that of the reptile in the greater size of the cerebrum, and the more complex structure of the cerebellum; it differs from the brain of a mammal in the smaller size of the cerebellum, and the rudimentary state of the fornix; and it differs from the brain of every other vertebrate class in the inferior position of the optic lobes. The cerebral hemispheres are generally of a convex condiform shape, with the apex directed forwards; they are disunited through their whole extent, being only joined by a round anterior commissure; they are destitute of convolutions, and have a small ventricle in their interior. The olfactory tubercles are greatly reduced in size, and retain their tubular communication with the cerebral ventricles. The optic lobes are small; gray on the surface, white internally, and contain each a small ventricle; they are connected by transverse medullary bands on which the pineal gland rests, with its peduncles directed forwards over the optic thalami. These last bodies are covered by the cerebral hemispheres, united by a commissura mollis, and destitute of transverse sulci. The medulla oblongata is large and wide; its components are marked on the surface, but it is without tuber annulare. The cerebellum presents a median vermiform lobe, and rudimentary hemispheres, sulcated transversely, with a faintly-marked arbor vitæ in the interior. The membranes investing the brain differ but little from those of the mammalia.

Nerves.—The nerves in this class present but few striking peculiarities, being distributed nearly as they are in man. The olfactory arise from the front of the hemispheres, pass forwards through distinct osseous canals in the cribriform plate, and are distributed in a radiated manner on the superior spongy bone. The large optic nerves arise from the optic tubercles, and form a perfect decussation in front of the infundibulum; where, as in the iguana, an incision displays a mutual intermixture of the fibres. The remaining cerebral nerves are distributed pretty nearly as in mammalia; the portio dura is, however, small in accordance with the insensibility of the superficial parts of the face. The spinal nerves correspond in number to the vertebræ; they arise by two roots, the posterior having a large ganglion on it. The sympathetic, which is well developed, communicates through the anterior lacerated opening with the fifth and sixth nerves. From the third cervical vertebra to the thorax, it is contained in the canal in the transverse processes, in company with the vertebral artery. It form a series of ganglions, from the base of the skull to the end of the coccyx; and communicates, in its course, with every neighbouring nerve.

MAMMALIA.

In this class the increased development of the nervous system is marked by the size and length of the spinal chord; the magnitude of the cerebrum and cerebellum, and the number of their gray deposits and commissures, as well as by the number and arrangement of the ganglions, together with the extent and systematic distribution of the great sympathetic.

The *spinal chord* is larger in proportion to the size of the body, but smaller when compared with the brain, in this than in any of the preceding classes; its internal canal has almost ceased to exist, and its lateral portions are more intimately united. It is shortest in man, quadrumana, and the tailless cheiroptera, and longest in the cetacea, where, as in apodal fishes, tadpoles, serpents, and the human embryo, it presents no posterior enlargements. In the long-tailed quadrupeds it extends to the sacrum; the posterior groove is generally shallow, though sometimes of considerable depth, as in cheiroptera and rodentia. The medulla oblongata is small: the corpora pyramidalia decussate very distinctly: the olivary bodies are small, and generally contain a corpus dentatum in their interior, and the transverse fibres of the pons or great cerebellic commissure are well seen.

Brain.—In the class mammalia, the cineritious matter bears a small proportion to the white substance. The convolutions are very superficial in the cetacea, edentata, ruminantia, and pachydermata, and wholly absent in the rodentia, and monotremata, as in birds; whilst they are deep in man, monkeys, and carnivorous animals. The optic lobes, without cavities, are smallest in man, quadrumana, and carnivora, larger in the herbivora, and largest of all in rodentia and edentata. A contrary ratio obtains respecting the development of the cerebral hemispheres, and the olfactory tubercles. The anterior and inferior cornua of the lateral ventricles, as well as the several commissures, are always present in this class. The posterior lobe of the brain, and the posterior cornua of the lateral ventricle, first appear in the quadrumana; the former has no convolutions.

The vast superiority of man over all other animals in mental faculties, led physiologists at a very early period to seek for corresponding differences in the brains of man and animals. They compared the weight of the brain with that of the body, and their researches led them to conclude that man had the largest brain in proportion to his body. Since the time of Aristotle till within a late period this opinion has been received: but more modern investigations have proved that the proportion of the brain to the body in some birds exceeds that of man, and that several of the quadrumana and some rodentia equal him in this respect. The illustrious Soemmerring proposed another mode of comparison, that of the ratio which the mass of the brain bears to that of the nerves arising from it, and in this point of view man is decidedly pre-eminent.

The brain of man far exceeds in size that of the simiæ compared with the nerves proceeding from it, and in these latter and in the seal it is larger in proportion than in other animals, while it is smallest in the glires, marsupialia, cheiroptera, and edentata. The largest brain which Soemmerring has found in a horse weighed 1 lb. 4 oz., and in an adult man was 2 lb. 5½ oz.: yet the nerves arising from the former were ten times larger than those of the latter. *Cœteris paribus*, small animals have a larger brain in proportion to their size, than large ones, and in cold-blooded animals its dimensions are very small, compared with those of a higher temperature. The following table shows the relative weight of the brain to that of the body in several of the vertebrate classes of animals:—

Fishes.—Silurus glanis, one-1887th; dog-fish, one-1344th; shark, one-2496th; carp, one-560th.

Reptiles.—Turtle, one-5688th; colubar natrix, one-792d; frog, (amphibious,) one-172d.

Birds.—Goose, one-360th; duck, one-257th; eagle one-260th; falcon, one-102d; sparrow, one-25th; canary-bird, one-14th.

Cetacea.—Porpoise, one-93d; dolphin, one-102d, one-60th, one-36th, one-25th.

Solipeda.—Ass, one-254th; horse, one-700th; one-400th.

Ruminantia.—Ox, one-860th; stag, one-290th; sheep, one-192d; calf, one-219th.

Pachydermata.—Wild boar, one-672d; domestic, one-512th; elephant, one-500th.

Rodentia.—Beaver, one-290th; hare, one-228th; rabbit, one-152d; rat, one-76th; mouse, one-43d; field-mouse, one-31st.

Carnivora.—Dog, one-305th, one-47th; fox, one-205th; wolf, one-230th; cat, one-156th, one-82d; ferret, one-138th.

Plantigrada.—Hedge-hog, one-168th; bear, one-265th; mole, one-36th.

Cheiroptera.—Bat, one-96th.

Lemurs.—Vari, one-84th; mococo, one-61st.

Baboons.—Magot, one 105th; great baboon, one-104th; macaque, one-85th.

Apes.—Mangabey, one-48th; the monk ape, one-44th; malbrouk, one-24th.

Sapajous.—(American apes) Coaïta, one-41st; Saï, one-25th; Saïmiri, one-22d.

Ourang-outangs.—The gibbon, one-48th; chimpansé, 26 inches in height, 11 oz. 7dr.

Child of six years, one-22d; adult man, one-35th.

The *Cerebellum* is smaller in proportion to the cerebrum in man, the saïmiri, and the ox, than in any others of the mammalia. In the human subject and in ourangs only, is it covered by the posterior lobes of the brain. The superior vermiform process and the hemispheres of the cerebellum are developed in every class in the inverse ratio of each other. In the saïmiri ape, the cerebellum is to the cerebrum as 1 to 14; in man and the ox, 1 to 9; in

the monk ape and the dog, 1 to 8; in the magot, papio, and wild boar, 1 to 7; in the saï and hare, 1 to 6; in the mole, 1 to 4; in the rat and beaver, 1 to 3; and in the mouse, 1 to 2.

Nerves.—The olfactory nerves are largest in the ruminantia, pachydermata, and carnivora, smaller in the cheiroptera and quadrumana, and discoverable with difficulty in many of the cetacea. In the squirrel, rabbit, hare, and other large-eyed nocturnal quadrupeds, the optic nerves are very large; they are small in rats, mice, bats, hedge-hogs, and subterranean moles, and in the sorex arraneus, mus typhlus, muscapensis, and others, they are said to be altogether wanting. They unite before the infundibulum, and form a partial decussation of their fibres. The third, fourth, and sixth nerves are distributed as in man, and are very small in subterranean animals. Of all the cerebral nerves, none reaches so great a degree of development as the fifth pair, in the inferior classes of animals and in the fœtal state of the human subject: it is also of enormous size in most aquatic birds. Its branches are freely and extensively distributed in those animals with proboscis, long muzzles, large lips, and broad bills, as the cetacea, ruminantia, pachydermata, carnivora, and ornithorhynchi, and also in those possessing horns. spines, bristles, and whiskers. This nerve is supposed to preside over the peculiar *instinctive* actions so remarkable in those grades of animals which indicate an inferior degree of mental endowment, and this opinion receives strength from the fact of its great size in the very early periods of human existence, when we know the actions are purely instinctive. The remaining cerebral, the spinal, and the sympathetic nerves are distributed so much after the human type as to merit no particular remarks.

In most mammalia the arteries of the brain form a complicated net-work around the petuitary body at the base of the cranium named *rete mirabile*, obviously designed to impede the flow of blood to the brain, in those animals with pendent heads. The veins occasionally run in osseous canals in order to avoid pressure; this is well seen in the cribriform plate of the mole's skull, and in the bony falx cerebri of the porpoise. A bony falx cerebri is also found in the ornithorhynchus, an animal which abounds in instances of anomalous structure. Animals which possess a bony tentorium are of far more common occurrence: it is well developed in most species of the cat and bear kind; it is not so well marked in the dog, seal, horse, and wombat, and it is merely rudimentary in the pig, the rabbit, and the mouse.

It has been generally supposed that these structures exist in such animals only as jump far, and that they served the purpose of protecting the respective portions of the cerebrum and cerebellum from undue pressure during these active movements, but this opinion is rendered quite untenable from the fact of their absence in many animals notable for jumping, as the wild goat, &c., and their presence in those animals alike remarkable for their slow and easy movements, as the bear. It is more probable they exist for the

purpose of obviating the concussion which would arise from the strong exertions in biting; for such exertions are made by all the animals which possess them, even by the horse in his wild state.

RECAPITULATION.

1. A nervous system exists in every class of animals, though not in all the animals of each class.
2. In the invertebrate classes it has a peculiar tendency to accumulate around the œsophagus.
3. In all the vertebrata its principal parts are protected by osseous sheaths.
4. The spinal marrow is tubular in the human embryo, and most of the lower vertebrata.
5. This system undergoes remarkable changes in the amphibia, during their metamorphosis.
6. It is highly developed, and with great uniformity in birds.
7. The chord presents enlargements corresponding in size to the members most used.
8. The spinal chord bears a large ratio to the size of the body in most mammalia.
9. Man's superiority is due to his mental faculties.
10. The brain is larger in proportion to the size of the nerves connected with it in man than in any other animal.
11. The fifth cerebral, or the nerve of *instinct*, is very large in most mammalia, and in the fœtal state of the human subject.

CHAPTER IX.

ORGANS OF SENSE.

General observations.—The organs of sense are those instruments which are placed upon the distal extremities of certain cerebro-spinal sensitive nerves, whose office being to establish a relation between the internal sentient principle and the external objects of surrounding nature, are necessarily placed in connection with the external surface of animals, and generally in the neighbourhood of the entrance of the alimentary canal. They are more numerous, more varied, and more perfect in the higher than in the lower tribes of animals, but they are more developed in the active insects and others of the articulata, than in the slow and torpid mollusca, and they attain their greatest degree of perfection in the vertebrata where the most complicated and delicate forms of organisation are consigned to their careful watch.

Vision.—Organs of vision have been figured and minutely de-

scribed in many of the polygastric animalcules; they vary in number from one in the polygastrics, up to eight in the acalepha. In the rotifera, optic nerves and ganglia are quite visible, and in the acalepha a lenticular body is superadded. Visual organs are met with in almost every class of the diplo-neurose division; in some there is but a single eye, in others they are more numerous, and placed apart on different aspects of the head. The medicinal leech possesses ten prominent eyes disposed transversely, and the neiris nuntia has two large pairs placed on the upper part of the head, and nearly a hundred smaller ones grouped around the mouth. Many of the higher insects present in their optical apparatus all the essential ingredients found in the highest forms of the organ. The eyes of the crustaceans, are generally compound like those of insects, and in many instances are moved by distinct muscles, and covered in front by a transparent layer of epidermis. In the crustacea, as in insects, the optic nerves enlarge into a ganglion in the globe of the compound eye, from which small filaments radiate to the several lenses of the component eyes.

Organs of vision are less required, and consequently less developed in the torpid mollusca than in the active articulata; they never form groups of simple eyes like the myriapods, nor compound organs like the insects and crustacea. In the acephalous mollusca they are simple, separate and numerous as in worms, but in the higher forms of gasteropods, pteropods, and so on, they are more complicated, and but two in number, disposed on the sides of the head as in the vertebrata; and in these possessing opaque coverings, as the inhabitants of bivalve shells, they are altogether wanting. In those, however, which enjoy rapid motion, as the pectem maximus, they are upwards of fifty in number, each being about a quarter of a line in diameter. The eyes of these animals are generally flattened in front, they possess a rudiment of membrana nicitans; the iris and the lids are usually motionless, yet in the general plan of their formation they form a near approach to the condition of these organs in the higher vertebrated classes.

In all the *vertebrata* the eyes are two in number, and with the exception of a few species, are symmetrically disposed on the sides of the head; the differences they present being chiefly referable to the density of the media in which the various animals reside. From the density of the watery element through which *fish* move, their eyes are generally of considerable size, except in the worm-shaped fishes, as the eel and the lamprey. Sometimes they are directed backwards or upwards as in the star-gazer: less frequently they are placed on one side, as in the sole. The eye is spherical posteriorly, and flattened in front. The conjunctiva is continued across in front of the cornea, and admits of easy separation from it in the eel and many other species. The eyelids are merely rudimentary and the lachrymal gland is wholly absent. The sclerotic tunic is thick, dense, laminated, elastic, and occasionally ossified anteriorly. The choroid is divisible into three layers, the internal or tunica Ruys-

chiana, the middle or the membrana vasculosa Halleri, and the external with its shining pearly lustre passes in front of the iris and produces the gold and silver colours so much admired. The cornea is remarkable for its flatness, the iris for its immobility, and the crystalline lens for its density, magnitude, and sphericity. The aqueous humour is scanty, the ciliary processes are rarely developed, and the yellow spot of Soemmerring is altogether wanting. Between the layers of the choroid, and embracing the optic nerve, a reddish mass of a horse-shoe shape is found in most fishes named *choroid gland*, which, according to some, secretes the colouring matter; according to others it is a sort of rete mirabile, and others again look upon it as an enlargement of the optic nerve, whilst the prevailing opinion at present seems to be, that it is a muscle destined to modify in some way the reflection of the rays of light. From the inner layer of the choroid another body, *campanula Halleri*, passes forwards towards the lens, somewhat analogous to the marsupium of birds. The pupil in fishes is large and round, and the eye is moved by four recti and two obliqui muscles.

The eyes of the *amphibia* are very large, and like those of fishes contain a small quantity of aqueous humour, and are flat in front. They enjoy great latitude of motion and are provided with palpebræ and a membrana nictitans; the superior lid is small and scarcely movable; the inferior large and very movable. The opaque integument veils the front of the eye in the proteus; in most other characters the eyes resemble those of fishes.

The *reptilia* present us with characters of eyes well suited to the rare medium they inhabit, such as convexity of cornea from abundance of humours, and a compressed state of the lens. Like the amphibia, they are furnished with three lids, but unlike them and fish, they are provided with lachrymal apparatus; they approximate the succeeding classes in many respects, as having ciliary processes, a movable iris, generally a vertical pupil, a dark pecten prolonged from the choroid into the vitreous humour, and osseous plates around the anterior margin of the sclerotic. In the chameleon only a small portion of the eye is to be seen through a narrow vertical slit between the margins of the lids, which conceal a large membrana nictitans.

We cannot fail to observe how the remarkable peculiarities presented by the organs of vision in *birds*, coincide with the vigour of their respiratory, circulatory, and locomotive systems. In all the other vertebrate classes we meet with instances, where the eyes, if not absent, are at least rudimentary, but in this class they are remarkable not only for their uniform existence but for their great size and perfect development. From the convexity of the anterior segment of the eyes and their lateral location, birds command an extensive sphere of vision, and in many of the high-flying rapacious kind, the organ is prolonged in front into a tubular form, but in aquatic birds the anterior half is more flattened. The sclerotic is thin, flexible, and elastic posteriorly; it is divisible into three

layers, between the middle and outer of which, from 15 to 17 osseous quadrangular plates are placed anteriorly, a repetition of what we have seen in reptiles and fishes; these scales overlap each other, they are connected by the sclerotic, and are capable of a limited degree of motion. The cornea is dense, and possesses a considerable degree of convexity, as well from the abundant humours as from the pressure of the surrounding muscles; and, according to the discovery of Crampton, it is capable of varying its convexity by the action of a muscular sphincter attached to the posterior layer at its circumference. The choroid is the same as in mammalia: the iris is remarkable for the freedom of its motions which, in some instances, seem voluntary: the pupil is generally circular, but elongated transversely in the goose and dove, and vertically oval in the owl. The chief peculiarity in the eye of birds consists in the *marsupium nigrum* or *pecten plicatum;* this wedge-shaped body, which in appearance simulates choroid, is composed principally of vessels, and extends from the entrance of the optic nerve through the vitreous humour towards the lens which it sometimes reaches, and gets an attachment to. Petit supposed that this substance rendered objects in front of the eye more distinct by absorbing the lateral rays of light: Home, that by its muscularity it retracted the lens; but this is impossible when it does not reach it. Owen considers it an erectile organ, destined to push forward the lens either directly or through the medium of the vitreous humour; others look upon it as a gland for secreting the vitreous humour, and many are of opinion that it is placed there for the purpose of absorbing the super-abundant rays of light during the exposure of the eye to the blazing sun when soaring aloft.

The aqueous and vitreous humours present no peculiarities; the lens is flat in high-flying birds of prey, and more convex in the aquatic species; it is not here as in the other classes an achromatic lens, in consequence of the absence of central nucleus. The globe of the eye is moved by four recti and two oblique muscles. The lower lid is the more movable in birds and is provided with a distinct depressor muscle. The third eyelid, or *membrana nictitans* is a conjunctival fold connected with the inner angle of the eye and capable of being moved across the organ by a peculiar pair of muscles. One of these, from its shape, is named *quadratus;* it arises from the upper and back part of the sclerotic; its fibris descend in a convergent manner towards the optic nerve, a little above which they terminate in a free semilunar aponeurotic margin, containing a canal. The second muscle called *pyramidalis* arises from the inferior internal and posterior part of the sclerotic, its fibres pass converging to the upper surface of the optic nerve, where it forms a slender tendon, which passes through the canal in the quadratus; it then passes from the outer to the lower surface of the sclerotic, conducted in a cellular sheath till it gains the free margin of the membrana nictitans, into which it is inserted.

By the simultaneous action of this pair of muscles the membrane

is rapidly and forcibly drawn downwards and outwards over the front of the eye, and is restored to its former situation by its own elasticity. The lachrymal gland is situated at the external angle of the eye, and at the internal angle there is another gland named Harderian, from its discoverer, but is nothing more than a congeries of mucous follicles to compensate for the absence of meibomian glands. There is a third gland in or near the orbit, called *nasal*, its secretion being wholly destined for the nose.

In the *mammalia* the organs of vision are constructed in perfect accordance with the media the animals move in; they are usually placed laterally, but in the nocturnal quadrupeds they are directed forwards as much as in man, and in the quadrumana even more so. The eyes are of a large size in ruminantia, rodentia and many pachydermata; and they are small in moles, shrews, whales, and in most cheiroptera. In the *mus typhlus* the eye is covered by hairy conjunctiva; and in the mole of Libanus, it is so small as to be almost invisible. The form of the eye is generally spherical, but in the cetacea flattened anteriorly as in fish, and in bats it approaches to that of birds. In the cetacea the aqueous and vitreous humours are less abundant than in terrestrial quadrupeds, the cornea is flat, the lens is large, dense, and round, and the sclerotic is an inch thick posteriorly in a whale, with an eye the size of an orange; the lids are imperfectly developed, the lachrymal apparatus is absent, and the superior oblique muscle of the eye is destitute of a pully; but the smallness of the eye in this order of mammalia, compared with that of fish, bespeaks a higher development of internal perceptive organs.

In the carnivora the cornea is prominent, the pupil vertically oval, the thick choroid without pigmentum nigum posteriorly, and a blue or green tapetum glitters in the bottom of the eye. The cornea covers half the eye in the rat and porcupine, and is elongated transversely in the marmot, and generally in ruminants. The tapetum also exists in the ruminantia, solipeda, pachydermata, and cetacea. In the dog, wolf, and badger it is white, bordered by blue. The iris is subject to numerous varieties as regards its colour, structure, and the shape of the pupil: the latter is of a circular form in the rodentia, bats, and simiæ; transversely oval in the ruminantia, solipeda and cetacea; in these instances the oval form does not seem to pervade the entire thickness of the iris, but only its external layer. The retina in carnivora, and many rodentia, as in some birds, is confined to the posterior half of the eye: in the former on account of the breadth of the corpus ciliare; in the latter on account of the width of the iris.

In the mammalia the eyelids are formed generally as they are in man, the superior being the larger and more movable, and the membrana nictitans exist in the entire class, with the exception of man, apes, and the cetacea. The ornithorhynchus histrix has but a single circular lid. In addition to the lachrymal gland, which is

found in all mammalia, except the cetacea, the glandula Harderi exists in the carnivora, ruminantia, pachydermata, and some rodentia. Instead of puncta lachrymalia, the hare and rabbit have a slit opening into the nasal duct; the eye is moved by four recti and two oblique muscles, and in many of the genus felis the superior oblique is perforated by the rectus superior: the inferior oblique has the same relation to the inferior rectus in the tiger, though not in the lion. All the muscles of the eye are said to be wanting in those animals in which the organ is in a rudimentary state.

Hearing.—When we consider the many services arising from this sense, such as indicating the approach of danger, conducting predaceous animals to their prey, the bringing together the two sexes, &c., we should expect to find, as we really do, an organ of hearing in almost every division of the animal kingdom. In the radiated division of animals no distinct acoustic organs have been detected; it is probable, however, that the undulations produced by the percussion of outward bodies in the media in which these low creatures reside, produce some impression, though feeble it may be, upon the general surface of their bodies. It is not till we ascend in the scale as high as the active air breathing insects of the articulata that we meet with special organs appropriated to this sense; and here they consist of auditory nerve, vestibule, and two rudimentary semicircular canals. In many of the inferior torpid mollusca there do not seem to be any particular organs devoted to the perception of sound, but in the higher cephalopods which approach the nearest to fish in their general characters, the organs of hearing present a similar degree of complexity.

Fishes, like the cephalopodous mollusca, receive their acoustic impression by undulations through the dense medium surrounding them, and in the lowest cartilaginous species, as the lamprey, the organ consists of a simple vestibule, and three membranous semicircular canals, separated from the cavity of the skull merely by dura mater. In the bony fishes the vestibule and semicircular canals are highly developed, fenestra ovalis appears, and by and by a rudimentary cochlea and tympanum without air are seen; in the cavity of the vestibule two or three small bodies are found, soft and pulpy in the cartilaginous fishes, but of a stony hardness in the osseous kind, and composed of carbonate of lime.

In the aquatic *amphibia* and in the tadpole state of the reptiliform species, the organ of hearing possesses a near affinity to that of fishes; it consists of the vestibular cavity containing its cretaceous bodies, the membranous semicircular canals, and fenestra ovalis closed by stapes, all contained in a cavity of the temporal bone, and covered externally by the common integument. But in the adult state of the frog and salamander the apparatus is more complicated, the semicircular canals are lodged in the temporal bone; the tympanum is closed by membrana tympani, contains three ossicula united, and communicates with the fauces by a Eustachian tube.

The *reptiles* present a higher development of acoustic organs; in

serpents, however, they closely resemble the caduci-branchiate amphibia, and by their vestibular saculus, containing solid cretaceous bodies, they resemble the osseous fishes. The cavity of the tympanum is larger in the saurian than in the ophidian reptiles. As we ascend to the higher orders, we meet with a cochlea, which is the last part of the internal ear that attains perfection, slightly curved and divided into a scala tympani and scala vestibuli.

In *birds* the organ of hearing resembles that of the crocodile; there is no cartilaginous external ear, and but a rudimentary concha, which, however, is compensated for, especially in rapacious birds, by a peculiar arrangement of feathers around the external meatus, which in general they can erect at will so as to catch distant sounds, and by that means either flee from danger, or pursue their prey through dark and gloomy places. The external ear of owls is furnished with a crescentic fold of integument in the form of a valve. The oval tympanum, surrounded by bone, communicates with the air-cells of the cranium by three large openings, and with the fauces by two short wide Eustachian tubes which open by a single orifice in the swan at the back of the posterior nares. There is but one bone in the tympanum analogous to the stapes, with processes rudimentary of the malleus and incus, and moved by a single tensor muscle, which comes from the occiput and increases the convexity of the membrana tympani by drawing it outwards. The cochlea, though more developed than in reptiles, has not yet reached perfection, and the other parts of the internal ear present no remarkable peculiarities different from the inferior grades of the next class.

In the *mammalia*, generally, the organ of hearing is distinguished by the development of a true cochlea; by an increased number of auditory bones; by the formation of external canal, and by the addition of an external movable ear. We will meet, however, with evident, though gradual, transitions from the simple state of organ already seen in the inferior classes, up to man, where it has attained its most complex and perfect condition. The concha is very small in otariæ, beavers, and otters, and wholly absent in the cetacea, seals, walruses, the mole, the manis, and the ornithorhynchus. The aquatic shrew and other mammalia which frequently go into the water, form an approach to the crocodlile in having the external auditory opening furnished with a valve. This external orifice in the dolphin is merely large enough to admit a pin, and from it a long narrow winding passage leads to the tympanum through the fat which lies under the skin. As we ascend through the mammalia, residing more exclusively on the land, the concha acquires greater size, and by the development of cartilage and powerful muscles it becomes to enjoy very free and varied motions. It is large, movable, and directed backwards in the ruminantia, pachydermata, cheiroptera, and especially in the timid and feeble rodentia; and in the carnivora it is small and inclined forwards.

The cavity of the tympanum communicates with the mastoid cells, contains four movable ossicula and three distinct muscles; it is

closed by a membrana tympani, which is concave externally, except in the whale. In the ornithorhynchus, which in so many points of view constitutes the connecting link between reptiles and the higher classes of animals, the external passage is long and singularly tortuous, the ossicula auditus anchylosed, the cochlea represents a curved horn, as in birds and reptiles, and the semicircular canals project into the cranium. The Eustachian tube is wide in the cetacea, it opens at the blowing hole, where it is furnished with a valve; the cochlea is short and convoluted in one plane in the cetacea, long, narrow, and spiral in the rodentia, and in the guinea-pig, porcupine, and aguti, it forms three turns and a half; the other essential parts of the labyrinth agree on the whole with those of the human subject.

Smell.—No organs subservient to this sense have been detected in the cyclo-neurose animals, but in the annelides of the diplo-neura, the sense is said to reside in the parietes of their mouths, or the pores of their air-sacs, and in the palpi, and antennæ of insects. The entrance to the respiratory passages, the sensitive tentacula, and even the whole surface of the body in the higher orders of the mollusca, are capable of receiving odorous impressions. The laminated organs of smell in fishes are placed in two small depressions on the anterior part of the face; they are protected by cartilage, lined by a delicate mucous membrane disposed in radiated folds in the pike: tufted in the cyprinus, and arranged like the barbs of a quill in the carp, ray, and shark. These cavities have no communication with the mouth or pharynx; they are closed in front by a valve formed of skin and cartilage, and a similar structure partly divides each into two.

In the perennibranchiate amphibia, as the proteus and siren, the organs of smell in every respect resemble those of fishes, and in the more highly developed genera, as frogs and salamanders, they approach in characters to those of reptiles. The nostrils are partly cartilaginous, partly osseous, and open into the cavity of the mouth. The olfactory nerves enter by two foramina in the ethmoid bone, and are distributed to every part of the soft pituitary membrane. In serpents the nasal cavities present rudimentary turbinated bones, and open posteriorly by a single orifice. The turbinated bones are larger and more curved in the sauria, and in the chelonia the olfactory surface is greatly extended and concealed by a strong osseous covering.

In birds the external nostrils vary much as to size, shape, and situation, they are generally free and wide, but in some instances very small, as in the heron and gannet. The septum narium is partly bony, partly cartilaginous, and covered by a highly vascular pituitary membrane in the swan. The nasal cavities in birds contain three turbinated bones and open separately into the pharynx, except in the cormorant where they join previous to their opening. The olfactory nerves are distributed exclusively to the membrane covering the septum narium and superior spongy bone. It is gene-

rally supposed that birds of prey are gifted with an acute sense of smell, but the experiments of Mr Audubon go to prove the reverse opinion; and according to the researches of Scarpa, the following is the order in which it is enjoyed, beginning with those in which it is most acute; *grallatores, natatores, raptores, scansores, insessores, rasores.*

The organs of smell in the mammalia are distinguished by the more perfect formation of external nose, by the large size of the nasal cavities, and by the latter receiving several new openings, such as the frontal, nasal, ethmoidal, sphenoidal, and maxillary sinuses. The external openings are valvular in the beavers, seals, and camels, and variously modified in other animals, according to their different habits, as in the hog, elephant, &c. The turbinated bones are long and simple in the rodentia, ruminantia, and pachydermata, and they form a complicated series of labyrinths in the carnivorous tribes, where an acute sense is so necessary to enable them to pursue their prey through their dark retreats. The large olfactory nerves pass through the numerous openings of the cribriform plate, except in the cetacea, to be distributed on the surface of the turbinated bones. These nerves are large and hollow in the human fœtus, like the olfactory tubercles of quadrupeds, and it is interesting to observe how the sense of smell preponderates over all others in the new born child, this can be easily tested during the nuzzling of the infant at the mother's breast, when the loudest sounds may assail its ears without effect, and when its visual powers are limited to the mere perception of intense light.

Taste.—A considerable degree of obscurity prevails, respecting the enjoyment of this sense in the different classes of animals, and although we cannot display any organ especially appropriated to it in the inferior tribes of animals, yet it is supposed that all enjoy it, from the polygastric animalcules up to man. It is generally seated in, but by no means confined to the tongue, this organ being absent in some instances even in the human subject, where the existence of the sense has been proved; and in other cases, where the tongue does exist, its dense horny nature excludes it from such an enjoyment. The form of the tongue differs considerably in different animals; in none, not even in the simiæ, is it exactly like that of man. In the cephalopods distinct gustatory villi cover its surface; in many fishes it has no papillæ, and in others it is set with teeth; in the chameleon it is an organ of very peculiar mechanism, and admits of being protruded for several inches in pursuit of prey, with amazing celerity and precision. This power, for a long period a paradox with naturalists was discovered by Dr. Houston to be of an erectile nature. In birds it serves chiefly as an organ of prehension, in a few only does it possess papillæ, being generally sheathed in front by horn. With few exceptions among the edentata, the tongue in the mammalia serves as an organ of taste. In the bisulca it is covered with a thick epithelium; in the bat, the opossum, and

especially the lion, and others of the cat kind, it is beset with strong sharp prickles, for prehensile purposes.

Touch.—This is the most general as well as the most simple of the senses, and the degree in which it exists has reference to the state of the tegumentary membrane, and the condition of the nervous system. In the invertebrata no organs solely devoted to the perception of sensitive impressions have been detected, yet there is little doubt but that the cilia of most polygastrics, the tentacula of zoophytes and mollusca, and the antennæ of myriapods and insects are subservient to this sense. Some fishes have fleshy sensitive filaments arranged around the mouth after the manner of tentacula, and others have only the skin on the abdomen, or about the mouth, uncovered with scales, and capable of receiving external impressions. The tongue among serpents, and the tail among saurian reptiles, and some mammalia, constitute their chief tactile organs. The organs of touch in birds are the bills, the cire in the falconidæ the wattles of the cock, and the caruncles of the turkey. It must be acknowledged, however, that this sense is very limited in birds, which is in some degree compensated for by the free distribution of the fifth pair of nerves to their horny bills, especially those of the aquatic species, which procure their aliment from mud.

In many of the mammalia the skin is shielded from external impressions by the presence of horny or spiny coverings, dense furs, or thick hides; and it is not till we arrive at the higher orders of quadrupeds, carnivora and quadrumana, that the organ of touch makes any approach to the perfect development of it observed in the human subject.

RECAPITULATION.

1. Organs of vision exist in every class of animals, and in the lowest orders the eyes vary in number from one to near 100.
2. In the vertebrata the eyes are two and vary much in form and situation.
3. No organs of hearing or smell have been detected in the radiata.
4. Our knowledge concerning the organ of taste is involved in much obscurity.
5. No organ of touch has been detected in the invertebrata.

CHAPTER. X

ORGANS OF DIGESTION IN THE INVERTEBRATA.

General observations.—The organs engaged in the function of digestion may be arranged under two heads: the primary, or

essential—including the alimentary tract; and the secondary, or tributary, embracing the liver, spleen, pancreas, salivary, and mucous glands.

There is no organ so universally present, nor so essential, as an internal digestive cavity, and hence so often alluded to as constituting a line of distinction between the animal and the vegetable kingdoms; indeed there is no class of animals without it, although it is not found in every species of each class. The peculiarities presented by the digestive apparatus will vary according to the rank an animal holds in the scale of the creation, the kind of food on which it is destined to subsist, and the elaboration that food may require to undergo. The alimentary surface of a plant is the exterior of its root spread out in the earth, and absorbing, by its spongioles, the materials for its nutrition, but the alimentary surface of an animal is internal, and continued from the skin, like the inside of a lady's muff.

Cyclo-neura, GRANT—*Radiata*, CUVIER.—In the very low tribes of animals the digestive apparatus presents characters equally diversified as the forms of the creatures themselves. The alimentary cavity has often but one orifice; there are seldom teeth or glandular organs, and the food is generally of the simplest sort. In the *polygastrica*, as the term signifies, the cavities are numerous, and their various forms have been well observed by Ehrenberg, who caused these transparent animalcules to swallow fluids coloured with carmine, indigo, or sap-green. The monads and several other genera have but one orifice which receives the openings of the several cavities, and from the absence of intestine the entire group has been named *anentera*. In the higher forms, however, the alimentary canal is furnished with an oral and an anal orifice, the straight, curved, or spinal intestine receives the openings of numerous cœcal appendices through its whole course. In some of the small monads *no* internal cavity has been detected, and in other genera the number varies from one up to two hundred, as seen in a paramæcium. Many species are provided with dental organs in the form of stiff spines disposed around the mouth, but in none of the class have tributary or glandular organs been observed.

The *porifera* present a very simple form of alimentary apparatus, their absorbent canals closely resembling the ramified roots of plants, and as we ascend through the diversified series of the *polypifera* or zoophytes we perceive the system increasing in complexity from the simple genito-digestive sac of the hydra up to the complicated structure presented by the actiniform polypi, where the stomach is provided with a muscular and mucous tunic lined with vibratile cilia, and communicates inferiorly with the genital cavities. The greater number of the *acalepha* possess a simple broad and radiated alimentary cavity, suited to their highly organised and minutely divided food, but in the monostomatous species, which live on coarser aliment, a cartilaginous masticatory apparatus and biliary secretion are superadded. The torpid predaceous *echino-*

dermata afford in the structure of their digestive organs, connecting links of transition from the radiated to the articulated classes. In the higher forms of the echinida strong masticating and salivary organs are provided, the anal orifice, which in the lower tribes is placed on the inferior surface, gains a dorsal aspect, which it continues to hold in the holothuriæ and articulated classes. Thus we perceive the digestive cavity, from being a simple monostome sac, gradually acquires the form of a long narrow canal, open at both ends, and furnished with salivary and biliary organs.

Diplo-neura, GRANT—*Articulata*, CUVIER.—The carnivorous character of this great division of the animal kingdom bespeaks an alimentary canal, limited in its capacity, straight in its form, and simple in its structure. This canal usually takes a horizontal direction, opens at the two opposite extremities of the body, and is provided at its commencement with prehensile, destructive, or masticating organs. In consequence of the simple nature of the food on which the *entozoa* subsist, many of them have but a single orifice to their digestive sac. In the higher and more perfect forms, however, of these as well as of the *rotifera*, the canal passes straight or slightly winding through the body, presenting an oral and anal aperture, and surrounded by the genital and biliary organs. The *cirrhopoda* are remarkable for the great size of their salivary and biliary apparatus, and the wide ducts of the latter, which open into the stomach, as in most of the invertebrated tribes.

Among the *annelida* the earth-worm is remarkable for its capacious mouth, a small salivary gland, a sacculated stomach, consisting of three continuous cavities, and a narrow, slightly bending intestine. The leech has three horny maxillæ, furnished with sharp teeth, with which it inflicts its tri-radiate wound, the straight, irregularly sacculated intestine is furnished with ten pairs of lateral cœca, and enlarges into a small sac near the anus. The carnivorous *myriapods* are provided with three pairs of salivary and two poison-glands, by their contracted œsophagus and elongated membranous stomach, they resemble the higher species of worms, and by their small, narrow intestine, ending in a wide colon, they are allied to the ophidian reptiles.

The digestive organs of the *insecta* present in an embryo state nearly all the essential elements of the chylo-poietic system in the highest classes of animals, as masticating organs, salivary and mucous glands, liver, pancreas, &c.: they will be found to vary, however, according to the peculiar living habits of the species, and the quality of their food. The alimentary canal usually consists of a wide pharynx, a narrow œsophagus, a dilated crop, a muscular gizzard, provided with sharp, conical, horny teeth, a capacious chylific stomach, a straight, narrow intestine, a short, dilated colon, and a contracted cloaca. In the herbivorous insects, the alimentary canal is long, capacious, and complicated. The gall-bladder is usually single, but occasionally double. The cunning carnivorous *arachnida* resemble the insects in the arrangement of their

masticating organs, whilst their straight narrow alimentary canal and the compact state of their liver, ally them to the crustacea.

Like most other carnivorous articulata, the cunning, cruel, aqautic *crustaceans* are provided with prehensile and masticating organs well suited to destroy the prey in the rich element they inhabit. The maxillæ vary from one to five pairs, but are wanting in the lower orders. The alimentary canal is generally without convolutions, and opens by two apertures. The decapods present a narrow œsophagus, leading to a capacious muscular stomach, furnished with numerous solid calcarious teeth, and a straight intestine occupying the dorsal portion of the trunk, and receiving near its commencement the biliary and pancreatic ducts. The salivary glands are absent except in the higher orders, where rudiments of them are perceived surrounding the œsophagus. The mucous membrane forms rugæ in the œsophagus and stomach, but not in the intestine, and the peritoneum forms no mesentery.

Cyclo-gangliata, GRANT—*Mollusca*, CUVIER.—This great division of the animal kingdom being destined chiefly to subsist on soft food, masticating organs are little required by them, hence they are often but slightly developed, and in some cases wholly absent. But their food is greatly varied and often coarse, so as to require a complicated form of alimentary canal, and a high development of glandular apparatus. The digestive organs of the *tunicata* closely resemble those of the *conchifera*, being a little more complicated in the latter. Both are destitute of prehensile or masticating organs. and depend for their supply of food on the respiratory currents. They possess a short wide œsophagus, opening into a capacious muscular stomach, without teeth, and receiving the biliary ducts. The intestine is generally short, wide, and convoluted. The conchifera differ from the tunicata by their long and convoluted intestine passing between the two aortæ, through the fleshy substance of the ventricle, and the mass of the liver. The terrestrial pulmonated *gasteropods* present a more complicated digestive apparatus than the acephalous mollusca, especially those which feed on vegetable substances. They are provided with a pair of horny jaws, a muscular tongue and proboscis armed with sharp recurved spines, a large pharynx, a long œsophagus, and a capacious stomach, divided in the phytophagous species, into several compartments, furnished internally with teeth, and receiving the biliary and pancreatic secretions. One or two pairs of salivary glands lie around the œsophagus, and the liver is of considerable size. The intestine is long and convoluted, and opens in common with the genital organs on the right side, near the anterior extremity of the body. In the *pteropods* and *cephalopods*, the œsophagus passes through the cranial cartilage and ganglionic ring, sometimes dilating into a crop before entering the muscular gizzard, which is often lined with a thick coriaceous epithelium. The intestine is short and wide in the carnivorous species, destitute of cœcum-coli, not distinguished into large and small as in the vertebrata, and no where

imbedded in the substance of the liver, as in many of the inferior mollusca. The mollusca are without *gall-bladder*, and as yet no portal circulation has appeared. The entrance of the hepatic duct into the stomach is guarded by a pair of prominent valves, prolonged so into the intestine as to allow of the passage of the pancreatic and biliary secretions into the gut during a state of vacuity without entering the stomach or duodenum.

CHAPTER XI.

VERTEBRATA.

In this great department of the animal world the digestive apparatus presents a higher development and a greater degree of complexity than we have met with before. The alimentary canal always swells out into a distinct gastric enlargement, and is provided with a large conglomerate liver, spleen and pancreas. The duodenum invariably receives the biliary and pancreatic secretions, and the salivary glands are rarely absent. The teeth are generally confined to the alveoli, and there are none found in the stomach. As a general rule the canal is longer, larger and more sacculated, and the masticating and glandular apparatus more developed in the phytophagous than in the carnivorous tribes.

PISCES.

Since vegetable food cannot be procured in the unfathomable depths of the sea, we are prepared to meet with a short and simple form of alimentary canal in fishes, suited to their predaceous habits. Vegetable substances might even endanger their lives by an evolution of gas which would render them specifically lighter than the water, and cause them to float upon its surface with the belly upwards. The teeth of fishes are generally numerous, destitute of fangs, laminated, deciduous, thinly covered with enamel, and movable on the surface to which they adhere, till maturity, when they become permanently fixed. The teeth of fishes are often implanted in the tongue as in many gasteropods and birds, in the vomer as in amphibia, in the palate bones as in serpents, in the pharyngeal bones, branchial arches and os hyoides, as well as in the maxillary and inter-maxillary bones to which they are confined in the saurian reptiles and mammalia; the teeth are most numerous in the pike and salmon, and are altogether wanting in some genera, as the sturgeon. As in serpents, crocodiles, dolphins, and other predaceous non-masticating vertebrata, the teeth are not opposed to each other but placed alternately, adapting them to their prehensile office.

The tongue is broad, short, and almost destitute of papillæ. The salivary glands are only rudimentary, and even wanting where the liver and pancreas are well developed, but the mouth is well supplied with mucus. The short, wide infundibuliform œsophagus has an external circular, and an internal longitudinal layer of muscular fibres, and is lined with a pale, villous, longitudinally plicated mucous membrane provided with numerous mucciperous follicles. The large gastric cavity is sometimes long and tapering as in the herring, and sometimes globular as in the lophius: its two orifices are closely approximated, so that the food is retained in it for a long period, hence, if we feed a tame perch till it is gorged, it will not eat again for ten or fourteen days; both orifices of the stomach are sphinctorial, its mucous membrane is plicated and forms a valve at the pylorus with a fringed margin, surrounded by a ring of cartilage. The intestine, in many cases, does not measure more than half the length of the body, in others, however, as the sword fish, it forms several convolutions, but rarely does it admit of any distinction into large and small. In the sturgeon, ray, and shark the anal is smaller than the cardiac portion, and the reverse obtains in the pleuronectes, gadi, murœnæ, &c. In order to compensate for the shortness of the canal and the absence of valvulæ conniventes, the lining membrane is peculiarly disposed, being reticulated in the sturgeon, forming spiral turns in the shark and ray, and serpentine folds in the eel. The rectum here as in oviparous vertebrata, terminates in the cloaca through which are discharged fæces, urine, semen, and ova. On either side of the anus there is an oblique valvular opening, admitting of free egress, but prohibiting any thing from without, and the air-sac, or rudimentary lung communicates by a membranous tube with the œsophagus, stomach, or upper portion of the intestine.

The large elongated liver is of a soft texture, light colour, and divided into many lobes, it is provided with arterial and portal circulation, and generally with a large *gall-bladder* as in other predaceous vertebrata. Several long hepatic ducts join the cystic, and many short ones run at once into the fundus of the gall-bladder, and the short but wide choledochus either opens separately or in common with one or more of the pancreatic ducts into the upper portion of the intestine. The spleen is small, of various forms, attached to the side of the stomach, generally simple, but lobulated in the shark and sturgeon, as in some of the cetacea, and in the lamprey, which has neither pancreas nor gall-bladder, it is wholly absent, as in the invertebrata. The pancreas which is wanting in the centriscus, presents every stage of development, from one or two simple follicles as in the lophius, chœtodon, &c., up to a large, compact, reniform mass, enveloped in a muscular tunic, as in the sturgeon and xiphas. The large pancreatic follicles are connected by loose cellular tissue, and admit the digested food into their interior, like the biliary tubes of some mollusca. The peritoneum lines the walls of the abdomen, and surrounds the viscera in the same

manner as in snails, and the sepiæ: it form a small mesentery and a rudimentary epiploon, and it presents the remarkable peculiarity of its cavity communicating with the surrounding medium by the two small openings, placed at the side of the anus.

AMPHIBIA.

These animals, like the fishes, are predaceous in their habits, and swallow their food without mastication. The whole of them have prehensile teeth in the palate; salamanders have them in both jaws, frogs in the upper only, and the toad and pipa in neither, but in the toad two small transverse rows exist behind the posterior nares. The teeth in the proteus nearly resemble those of the salamander, but in the siren they are arranged in a quincunx order as in many fishes, and amount nearly to two hundred. The salivary glands are absent in the aquatic, and merely rudimentary in the terrestrial amphibia. In the toad and perennibranchiate amphibia the tongue is short, thick, and fleshy, but in the frog it is long, free, bifid, covered with papillæ and mucous follicles, as in reptiles The short, dilatable, fleshy œsophagus, leads to a narrow, transversely elongated stomach, muscular in it parietes, and overlapped by a large bilobate liver with a distinct *gall-bladder*. In the young tadpole of the frog the almentary canal is very long, the intestine which is narrow and coiled, measures ten times the length of the space from the mouth to the anus, but after the metamorphosis has occurred, and that the mixed food of the tadpole is changed for that of a more nutritious nature, as snails, worms, &c., the canal becomes gradualy shortened to one fourth of its former length. The duodenum has transverse folds like valvulæ conniventes, and the short, wide colon ends in the cloaca, together with the openings of the genital and urinary organs. The mucous membrane forms longitudinal folds in the proteus, the triton, the pipa, and the salamander; transverse folds in the frog, and quadrangular cells in the hyla. A small pyloric valve exists in the toad and pipa, and the valve of the colon is distinct in the frog, the triton, and the hyla. The liver, the spleen, and the pancreas are found in all the amphibia, varying in shape according to the form of the animal. Thus we perceive in the lower orders of amphibia, an evident approach in their digestive organs to those in fishes, in the great number of teeth, shortness and width of œsophagus, absence of fundus to the stomach, want of distinction between large and small intestine, and the magnitude of the liver. But in many we discover an approximation to the higher vertebrata, in having fewer teeth, an elongated tongue, fundus to the gastric cavity, distinction between large and small intestine, absence of pyloric and colic valves, and the development of transverse folds in the duodenum.

REPTILIA.

The ophidian and saurian reptiles chiefly subsist on animal food, therefore their digestive apparatus will be found to differ from that of the chelonia which live on vegetable substances. The teeth of serpents are sharp, conical, inverted, unopposed, and set in loose, movable bones, adapted for seizing and lacerating their prey, they are attached to the maxillary, inter-maxillary, sphenoid, and palate bones, and the poison fangs of the venomous species are perforated and grooved in front to transmit the secretion of the poison gland forced out by muscular pressure. The tongue is long, smooth, sheathed, and bifurcated. The salivary glands vary in the different species; the sublingual is always present, and the poison gland, which is analogous to the parrotid, is confined to the noxious species, and is placed below and behind each orbit. The long, distensible œsophagus, copiously supplied with mucus, leads to the long, straight, capacious stomach, longitudinally plicated and capable of being distended to many times the size of the body; it tapers to the pyloric orifice, which is provided with a distinct valve, and embraced by sphinctorial fibres. The duodenum presents a villious surface, and receives the pancreatic and biliary ducts; the remainder of the small intestine is narrow and convoluted to the commencement of the short, dilated colon, where there is generally a circular valve and a small cœcum. The colon ends in the cloaca together with the ureters, oviducts, or vasa deferentia, and the male organ of generation, single or divided, also passes through the cloaca, as in other oviparous vertebrata. The liver, spleen, pancreas, the kidneys, the testes, and the ovaria present an elongated form conformable to the shape of the body. The small intestines are attached to a mesentery, and the large are often sacculated for the purpose of retarding the passage of the food.

As most of the sauria are carnivorous like the ophidia, they present a form of alimentary apparatus equally simple. Their prehensile teeth are fewer and chiefly restricted to the jaws; the stomach is short and round in the form of a gizzard, with a pair of central tendons; the small intestine is long in the phytophagous species as the scincus and iguana, and in all other respects they resemble the ophidian reptiles.

The phytophagous chelonia present a higher development of alimentary canal than the carnivorous species. The place of teeth is supplied by the sharp horny margins of the jaws; the tongue is covered with long papillæ; and the salivary glands are variously developed in the different species. The long, wide, muscular œsophagus leads to a large fleshy stomach, extended transversely, and without a pyloric valve. The intestine is about six times the length of the body, and the colon presents a short, wide cœcum, and a circular valve at its commencement in the terrestrial, but not in the aquatic species. The alimentary canal is wide and muscular, and

the mucous membrane folded longitudinally so as to form a surface of considerable extent. The rectum dilates into a cloaca which receives the openings of the urinary and genital organs.

AVES.

Nothing can be more beautiful to observe than the rigid economy which is displayed in the accurate adaptation of the digestive apparatus of birds to the various and dissimilar kinds of food on which, from their diversified living habits they are destined to subsist. The absence of teeth in this class is supplied by strong horny beaks and powerful muscular gizzards, the former performing the part of cutting, and the latter of grinding teeth; the form of the bill will vary according to the food of the different species of birds and their mode of procuring it, thus in the climbing frugivorous maccaws, parrots, and cockatoos, it is broad and powerful to break the hard shelly coverings of seeds, and most of the granivorous order have a similar structure. The broad bills of ducks, geese, and other aquatic species are well adapted for obtaining worms and other substances from watery or muddy situations, whilst the eagle, the hawk, the owl, and other rapacious birds have short, strong, arched, dense bills, with cutting edges, equally suited to seize, cut, or tear their living prey. The tongue, which in birds serves the purpose of a prehensile organ, is as variable in form as the bills, being long, broad, and covered with recurved spines in the swans; short, round, and flexible in the parrots and cockatoos, and short and muscular in the struthious birds. The tongue of the flamingo is very remarkable, it is composed of an elastic, cellulo-fatty substance, its form is nearly cylindrical, the pointed apex being supported by an osseous plate inferiorly. A deep groove runs along the centre of the upper surface with a row of recurved spines on either side. The os hyoides in this class very much resembles that of reptiles, and the length of its glosso-hyal element chiefly determines the length of the tongue.

Since the food for birds remains but a short time in the mouth and undergoes very little change there, their salivary glands are small. In the crow they consist of a series of conical follicles situated along the sides of the mouth, and opening separately on its mucous surface; in most other birds, however, there are four pairs, one under the tongue, another at the junction of the angles of the lower jaw, another close to the cornua of the os hyoides, and the fourth is placed at the angles of the mouth: they are most developed in the frugivorous species. The uvula and velum are not present, and the narrow laryngeal aperture is protected by the retroverted papillæ at the base of the tongue, except in the coot, the albatross, and a few others where the epiglottis exists merely in a rudimentary form quite insufficient to cover the opening.

There is a remarkable pouch under the jaw of the pelican which serves as a net for seizing fish, and is capable of containing ten

quarts of water; a similar provision is found in the swift, the rook, the male bustard at maturity, and other insectivorous birds. The alimentary canal is much longer and more capacious, and the glandular apparatus better developed in the phytophagous birds than in those which subsist more exclusively on animal food. The long, wide, fleshy œsophagus, with a cuticular lining, passes down behind and to the right side of the trachea, behind the heart and between the lungs. In rapacious birds it is capable of enormous dilatation, but in the flamingo its diameter does not exceed half an inch. In the frugivorous, insectivorous, and omnivorous birds, the œsophagus presents nearly a uniform capacity all through, but in the raptorial eagles and vultures, which gorge themselves at uncertain periods, it forms a lateral dilatation at the lower part of the neck termed the *ingluvies* or *crop*. And in those birds which live exclusively on, and require to take a large quantity of vegetable food, the crop is large, globular or oval, single in the common fowl, and double in the pigeon; it is altogether wanting in the swan and goose. The œsophagus and crop are supplied with an abundant mucous secretion, and are provided with an external circular and an internal longitudinal set of muscular fibres, the reverse of the disposition observed in the human subject. Mr. Hunter has recorded in his animal economy, some interesting observations on the crop of the pigeon, from which it appears that this macerating paunch takes on a secreting function during the breeding season, and supplies the young pigeons with an abundance of milk, a diet suitable to their tender age, and the analogy of the pigeon's milk to that of the mammalia has not escaped popular notice.

That part of the œsophagus which extends from the crop to the gizzard, was called by Mr. Hunter the lower œsophagus; at its inferior part, just above the gizzard, it dilates into the glandular division of the stomach, variously termed the *proventriculus*, *ventriculus succenturiatus*, *bulbus glandulosus*, *echinus*, *infundibulum*. In the omnivorous and piscivorous tribes there is no perceptible dilatation here, but in all it presents increased vascularity as it is provided with a number of glands which secrete a fluid analogous to the gastric juice. Beneath the infunbulum is the powerful muscular gizzard directed transversely like the stomach of the vertebrata, overlapped by the lobes of the liver, and lined internally with a thick, dense epithelium. At the upper part of the gizzard are two openings, one large, to the left side, and communicating with the proventriculus, the other smaller, and a little to the right, leads into the duodenum. In those birds which feed on grain and other hard substances, the muscular fibres of the gizzard are distinguished by their density and red colour, they are arranged in four masses, two lateral, called the digastric muscles, and connected to anterior and posterior tendons, and two smaller ones between these, at the end of the gizzard, termed musculi intermedii. In rapacious and carnivorous birds the parietes of the gizzard are thin and membranous, yet distinctly presenting the anterior and posterior

tendons. The gallinaceous birds, in which the gizzard is most powerful, swallow pebbles and other hard bodies, which serve the purpose of reducing their food, like the gastric teeth of crustacea, insects, and gasteropods; but in the carnivorous birds, with a thin membranous gizzard, no such substances are required, all the necessary changes being effected by the activity of the gastric secretions. The parietes of this organ are subservient in a remarkable manner to a known law, to which the whole muscular system yields, that of increasing its growth in proportion to the functions imposed on it; this was strikingly illustrated in the case of a sea-gull, which Mr. Hunter kept for a year, living, contrary to its nature, upon grain. At the end of that period he contrasted its gizzard with that of another sea-gull, which had been living on fish, and found that the digastric muscles of the former had acquired nearly three times the development of the latter. He accomplished similar phenomena by changing the food of an eagle and of a tame kite, the former throve very well on bread, but that it was dissatisfied with its fare, is to be inferred from its seizing the earliest opportunity of breaking its chain, and effecting its escape. These facts show in a clear manner the provision of nature for the preservation of life under a variety of circumstances.

The intestine is shorter in birds than in mammalia, its different divisions are better marked than in the lower classes, and in the young bird a remnant of the entrance of the *vesicula umbilicalis* may be seen on the interior part of the small intestine in the form of a small cœcal appendage, and in many gallinaceous and some aquatic birds it remains through life. The course of the small intestine varies much in the different orders of birds; the duodenum always makes a long fold, which embraces the long, bilobate pancreas in its concavity. The large intestine is about a tenth part of the length of the body, and usually has two cœca at its commencement, except in the bustard and ostrich, it runs a straight course from the cœca to the cloaca; it is generally a little larger than the small intestine, and its villi are shorter, coarser, and fewer. The cœca coli are of great size in the gallinaceous and other granivorous birds, where they arise by two narrow canals, and enlarge into wide sacs, often several times the size of the intestine, as in the turkey. In the ostrich they have the mucous membrane disposed in the form of a spiral fold. They are least developed in the grallatores and the nocturnal rapacious birds. In the herons and several other birds there is but one, as in the invertebrate and lower vertebrate animals, and as in the plantigrade carnivora, they are altogether wanting in the zygodactylous birds.

The rectum terminates by a round valvular orifice in a dilatable cavity, the upper part of the *cloaca*, which is the remains of the allantois, and now forms a rudimental urinary bladder, and in the ostrich it serves for the retention of the urine as in the higher viviparous animals. At the lower and back part of this urinal por-

tion of the cloaca are the openings of the ureters, and external to these, the openings of the oviducts, or vasa deferentia.

To this *urethro-sexual canal*, succeeds the *preputial cavity*, or lower portion of the cloaca, which lodges the organs of excitement, clitoris or penis, as in reptiles, marsupial, and monotrematous mammalia. In the median plain, and on the dorsal aspect of the preputial cavity is the opening of a conical sac, named *Barsa Fibricii*, which lodges the anal follicles, and is analogous to Cowper's glands.

The liver is large in birds, especially in the aquatic species, it generally consists of two lobes, but occasionally of three, as in the pigeon, goose, and swan; the right lobe is usually larger than the left, the latter, however, is larger in the bustard, where it extends into the pelvis. The bile is discharged by two ducts, one goes directly to the duodenum, the other to the *gall-bladder*, and when the latter is absent, they both open separately into the duodenum, but in no case is there a ductus choledochus. The pancreas, long, narrow, and trihedral, is lodged in the fold of the duodenum, its ducts are two, sometimes three in number, as in the pigeon, raven, and common fowl, and they terminate separately in the duodenum. The small, round, oval, flat, or elongated spleen is placed beneath the liver, and to the right of the proventriculus; its texture is loose, and the blood would seem to be deposited in cells, from which the veins take it up.

When we contemplate the different lengths and forms of intestine met with in this class, we cannot help attributing it to some wise purpose, and a little reflection on the greatly diversified nature of the food on which the various tribes of birds are destined to subsist, irresistibly leads us to infer that economy seems to be the main design; for instance, the colon and cœca of the African ostrich, which has to subsist on the scanty and uncertain fare of the desert, are *fifty* times the length of the same parts in the cassowary, which inhabits Java, one of the most fertile countries on the globe.

MAMMALIA.

The digestive organs vary more in this than in any other of the vertebrated classes, and the varieties will be found to refer chiefly to the type of development and living habits of the sundry species. The teeth present infinite varieties as to form and position; however, their density and fixedness are well calculated to disintegrate alimentary substances, and blend them with the mucous and salivary secretions. The teeth are wanting in the ant-eaters, pangolins, and the whalebone whale. The young ornithorhynchus paradoxus has two molar teeth in each jaw on each side: these are shed in the adult animal, and replaced by one large one on each side. But in the hystrix there are twenty small, blunt, horny teeth, near the base of the tongue, and seven transverse rows in the corresponding surface of the palate. The incisor, canine, and molar teeth exist in the quadrumana, carnivora, ruminantia, without horns, and in most

of the pachydermata; but it is only in the extinct anoplotherium among mammalia, that the three kinds of teeth are arranged in an uninterrupted series, as in man. The superior incisors are wanting in the ruminantia, and the inferior in the walrus. The Ethiopian hog and certain bats lose their incisors at a particular age. The canine teeth are absent in the rodentia, some ruminants, and in most of the female solipeda. The rodentia have but two incisors in each jaw, with the exception of the hare and rabbit, which have them double in the upper jaw; the kangaroo has two below and eight above; the daman two above and four below. The molar teeth are the most essential, and are the last to disappear: hence the ornithorhynchus paradoxus, the tatu, and the two-horned rhinoceros, are restricted to them. The molar teeth are renewed eight times in the elephant, the incisors are shed twice in many rodentia; and most of the teeth are renewed once in the other orders of the mammalia. In most mammalia which feed on animal substances, the crowns of the teeth are entirely covered with enamel, and only partially so in the phytophagous quadrupeds.

The following is an outline of the process by which the *teeth* are *produced.* About *two months* after conception, a gelatinous substance lies along each alveolar arch: at the *third* month this substance is firmer, and lodged in a shallow groove in the bone. It is next divided into separate pulps by transverse filaments passing from one side of the alveolous to the other. These pulps are enclosed in, and connected by vessels to a thin vascular membrane, which, between the third and *fourth* month begins to secrete the ossific laminæ from its outer surface. This membrane, with its contained pulp, is supplied from the dental vessels, and nerves, and is surrounded by a thick vascular sac, separable into two layers; the latter membrane is attached to the pulp only at its base, but is firmly connected by its outer layer to the gum; from which it derives its vascular and nervous supplies. It is from the inner surface of the internal layer of this sac that the enamel is secreted, and at this period it becomes thick and vascular, whilst the outer layer, which is only rudimentary in man, secretes the *crusta petrosa* in the graminivorous quadrupeds. After the enamel has been secreted, both layers of this sac become wholly absorbed, hence they have been termed the *deciduous membranes*, in contra-distinction to the *permanent*, which are described as *three* in number, one being the periosteum of the alveolus, another the periosteum of the root, and the third the periosteum of the dental cavity, which secreted the tooth. But in fact these three permanent membranes are simply a continuation of the periosteum of the jaw which first lines the alveolus, then descends, to form the periosteum of the root, and lastly passes up in the form of a hollow cone to enclose the pulp. The period at which the teeth appear in the human subject is very variable, some children being born with two or more, whilst in others they may not appear for two or even three years. From five to eight months, however, is the most usual period; they generally

appear first in the lower jaw, and proceed in the following order:—From 5 to 8 months, the four central incisors; from 7 to 10, the lateral incisors; from 12 to 16, the four anterior molars; from 14 to 20, the four cuspidati; and from 18 to 36 months, the four posterior molars.

The purposes of prehension are accomplished by sensitive fleshy lips, as in herbivorous quadrupeds, by a long, flexible tongue, as in the giraffe and ant-eaters, and by other organs such as the proboscis of the elephant. The salivary glands are largest in herbivorous quadrupeds, less in the carnivora, and least in the aquatic mammalia. The sublingual glands are wanting in cats. The velum palati is large, but the uvula is confined to the quadrumana. The os hyoides, is most developed in the herbivorous quadrupeds, and has been shown by Geoffroy to consist of twelve elements, a *glosso* and *basi-hyal* piece for the body, an *apo* a *cerato*, and a *styl-hyal* element for each of the anterior cornua, and an *ento* and *uro-hyal* for each of the smaller posterior cornua. This condition is sometimes found as an abnormal state in man. The œsophagus is wide and dilatable in the carnivora, and narrow and fleshy in the herbivora. The arrangement of its muscular fibres is the same as in man; and its mucous tunic, which usually forms longitudinal and but rarely transverse folds, is lined with cuticle, which in the carnivora terminates at the cardiac orifice in a fringed margin, but lines half the stomach of the horse, the rat, the hog, and some others of the pecora, and in the ruminantia it lines the three first cavities of the stomach. The œsophagus of the ornithorynchus hystrix is furnished with a peculiar valve at its commencement, and numerous papillæ at its termination, directed upwards, and its cuticular lining is continued through the stomach.

The animal nature of the food of the carnivora bespeaks a short and simple form of alimentary canal. In some, as the lion and the cat, the stomach is elongated in form, and its orifices remote from each other, this is particularly the case in the lynx; in others, as the racoon, it is nearly globular, and in all, with the exception of the seal, its interior is smooth, and almost without villi. The monotremata, cheiroptera, insectivora, and marsupialia, also present a simple stomach, a cœcal portion being but little developed. When, however, the food is of a more mixed character, the stomach becomes more elongated transversely, as in the quadrumana and others of the less carnivorous tribes. In most of the rodentia the thin cardiac portion forms a distinct cœcum, and is separated by a constriction from the pyloric muscular portion. Several of the pachydermata, marsupialia, edentata, and quadrumana, form a link of transition to the more complex stomachs of the cetacea and ruminantia in the formation of folds or cœca with cuticular linings. The intestinal canal is very short in these animals, the whole tract not exceeding three times the length of the body in the lion and wild cat. In the badger there is scarcely any distinction between small and large intestine: but in the lion, seal, and others, it is well

marked. The cœcum is small in cats, spiral in dogs, and generally absent with the colic valve in the mustelidæ. Valvulæ conniventes are scarcely developed.

In the cetacea the tongue is short, thick, fleshy, and but little susceptible of motion, and in the whale it often affords three barrels of oil. The teeth are prehensile, the salivary glands rudimental or deficient, and the œsophagus short and wide. In the phytophagous cetaceans the stomach is divided into a large cardiac, and a small pyloric portion, by a contraction which gives origin to two tubiform prolongations. The cœcum is simple in the dugong, and bifurcated in the manatee. In the zoophagous cetacea the stomach consists of four or five compartments, none of which, except the first, have any communication with the œsophagus, therefore no rumination can occur. The first cavity is small and lined with cuticle, which terminates abruptly at the narrow opening leading into the second. A small pyloric orifice leads to a dilated duodenum. There is scarcely any distinction between small and large intestine, and the cœcum coli is but little developed. Why so complicated a stomach should exist in animals nourished by the most digestible and highly organised food, is an anomaly for which we can offer no explanation, but one which, from its interest, courts early investigation.

The stomach of the kangaroo resembles the human colon and cœcum; the œsophagus enters near its left extremity, which is small and bifid; the stomach first extends towards the right side, and then upwards and to the left, in such a manner as to completely encircle the entrance of the œsophagus, and terminates at the pylorus by a contracted orifice. Its cavity gradually enlarges from the left extremity till it nearly reaches the pylorus, it then dilates into a round cavity with two lateral processes, and finally ends by a narrow orifice. It presents a sacculated appearance arising from the presence of anterior and posterior bands like those of the human colon, and the cuticle lines it to a certain extent on either side of the entrance of the œsophagus. This animal has been known to ruminate when fed on hard food. The kangaroo-rat and the vampyre bat present similar modifications of stomach but have no part of it lined with cuticle, and in the former there is a valve at the cardiac orifice. The intestine of the kangaroo corresponds in its great length and convolutions with the coarse nature of its vegetable food, and the cœcum is about fifteen inches long. At the cardiac orifice of the stomach in the beaver and wombat there is a large gastric gland, like the glandular infundibulum in birds.

The ruminating animals possess four stomachs; the first magnus venter, or *paunch*, receives the crude unmasticated food, while the animal is grazing. When this cavity is filled the animal retires to rest, and begins to ruminate; the unmasticated food, softened in the paunch, now passes in small portions into the second cavity, called *reticulum*, or honey-comb; from this it passes as a bolus up through the œsophagus to the mouth, where it is thoroughly masticated and insalivated; it is next conducted by the œsophagus to

the third stomach, termed *manyplies*, or omasum, and from thence into the fourth stomach called *abomasum*, or rennet bag. Of these cavities, the first is the largest, and the third the smallest. The three first are lined with cuticle, and the fourth, which is next in capacity to the paunch is lined with a soft mucous coat folded in the longitudinal direction. This is the proper digestive stomach, and is analogous to the digestive sac of carnivorous and higher quadrupeds. The fourth stomach of the ruminantia is the first developed ; in the earlier periods of life it is the largest, and the only one employed in digestion. The mechanism by which milk is transmitted directly into the fourth stomach during the period of suckling is this, the œsophagus enters just where the three first cavities approach each other, here it can open directly into the first or second stomach, but instead of terminating there, it is continued in the form of a groove with prominent lips, which admit of being drawn together so as to form a complete canal, which then constitutes a direct continuation of the œsophagus into the third stomach, but this cavity not having been distended with solid food in the young animal, it merely forms a tube through which the milk passes into the fourth stomach. In the adult animal the same mechanism continues, but here the third cavity having been already distended, receives the bolus after rumination.

In the ruminants without horns, as the dromedary, the camel, and the lama, a somewhat different but not less beautiful mechanism prevails, fitting them to live in the sandy deserts and arid plains they inhabit. In these animals the paunch consists of two compartments, the first of which receives the unmasticated food from which it is returned to the mouth, moistened by the fluid of the second or cellular compartment. After the cud has been chewed, the food passes along the upper part of the second cavity into the third, and from that to the fourth. When the camel drinks, the water passes directly into the second cavity, and when this is full it flows into the neighbouring cellular compartment of the paunch. In the bullock, the three first cavities are lined with cuticle ; in the camel it lines only the two first, and terminates just within the orifice of the third, the surface of which has a faint appearance of honey-comb structure. From the comparative view which has been taken of the stomach of the bullock and camel, it appears, that in the bullock there are three cavities formed for the preparation of of the food, and one for its digestion. In the camel, the two compartments of the first cavity answer the purposes of the two first stomachs of the bullock ; the second is employed as a reservoir for water only ; the third is so small and simple in its structure, that it is not easy to ascertain its particular office, whilst the fourth is that in which the process of digestion is accomplished.

As a general rule, it may be stated that the intestinal canal is long, large, and sacculated in the herbivorous tribes, and short, straight, and without sacculi, in the carnivora. Some remarkable exceptions, however, present themselves, for instance in makies,

mice, and shrews which are purely frugivorous, and in sloths, which live on vegetable food, the intestine measures only about three times the length of the body; whilst in the porpoise and seal, which live on animal food, it measures in the former 11 times, and in the latter 28 times the length of the body. But this apparent anomaly is explained by recollecting that the cœcum plays a compensating part with respect to the other portions of the alimentary canal, indeed the researches of the Heidelberg professors authorise us in believing that it acts the part of a second stomach, and that where the latter is simple, the cœcum presents a complex and highly developed condition, and vice versâ. Hence by a reference to the highly developed cœcum and vermiform appendix of the rodentia, we are enabled to reconcile their simple form of stomach with their herbivorous food. In the elephant, the small intestine measures 38 feet, the colon and rectum 20½ feet, and the cœcum 1½. In the camel, the small intestine is 71 feet, the colon and rectum 56, and the cœcum 3. The intestine is 10 times the length of the body in the horse, and 28 times in the sheep. In an ornithorhynchus 17½ inches long, the small intestine measured 4 feet 4 inches, and the colon and rectum 1 foot 4 inches. In this animal, the rectum, urinary, and genital organs terminate in a cloaca, as in birds and amphibia.

The solidungulous pachydermata masticate their food before it is swallowed, therefore they do not ruminate, and require but a simple digestive stomach; but they have the same narrow lengthened form of intestine, and a capacious sacculated cœcum and colon. The liver is largest in the cetacea and those animals that dive or burrow; smaller in the herbivora, and least in the carnivorous tribes. There seems to be no general law for the presence or absence of the *gall-bladder* in mammalia more than in birds and fishes; it is for the most part wanting in the herbivorous species, as the deer and the camel; it is also absent from most of the rodentia and pachydermata; and here the hepatic duct is generally much dilated, as in the horse and elephant. In the otter a similar dilation exists in conjunction with a gall-bladder. It is remarkable that all the mammalia which want this reservoir, except the porpoise, are phytophagous.

In the course of my dissections during my pupilage at the college, I, together with my esteemed friend, Surgeon Bewley, of Moate, met with a female subject about nine years of age, in which this receptacle was absent. I invited the attention of Dr. Houston to this, I believe, *unique anomaly*, who has prepared and deposited the biliary apparatus in the museum of the college.

The spleen is long, flat, and attached to the paunch in the ruminantia, narrow and lengthened in the carnivora, and in the porpoise it consists of several portions. The pancreas is long, flat, and attached to the right end of the first stomach in the cetacea, in other mammalia it is longer, and often divided into several portions, its

duct, which is double in the elephant, usually opens separately into the duodenum.

RECAPITULATION.

1. A digestive cavity is the most universal organ in animals, and exists in all, with the exception of some of the monads.

2. Masticating, salivary, and biliary organs are found in the higher radiata.

3. All these parts are more highly developed in the articulata, and one or two gall-bladders are present.

4. There has been no gall-bladder found in the mollusca.

5. The stomach receives the biliary and pancreatic fluids in all the invertebrata.

6. The invertebrated animals possess no portal circulation.

7. In the *vertebrata*, the alimentary canal always swells out into a gastric enlargement. The tributary organs are large and conglomerate, and the salivary glands are rarely absent.

8. The duodenum receives the biliary and pancreatic secretions, and there are no teeth found in the stomach.

9. As a general rule the alimentary canal is larger and longer in the vegetable-eating animals, than in those that live on flesh.

10. Fishes have a simple form of alimentary canal, their teeth are often numerous, as in the pike, rarely absent as in the sturgeon, their salivary glands are rudimental, or entirely wanting, and their whole canal often measures but half the length of the body.

11. The digestive apparatus undergoes interesting changes during the metamorphosis of the frog, &c.

12. The teeth are absent in birds, and their place supplied by bill and gizzard.

13. The crop is double in the pigeon, single in the fowl, and absent from the goose. The gizzard is thick and powerful in the granivorous, but thin and membranous in the carnivorous species, and the great intestine terminates in the dilatable rectal vestibule which receives the openings of the ureters, of the oviducts, or vasa deferentia, and of the Bursa Fabricii.

14. The teeth are greatly modified in the *mammalia*, being rarely absent, as in the manis or pangolin, the myrmecophaga and the echidna.

15. The digestive system is most complex in the herbivorous ruminantia, and most simple in the carnivora; in the latter the food requires but little elaboration, hence the form of the teeth, and the great strength of the jaws are admirably adapted for seizing and tearing their living prey, here also we have a simple stomach, and a short intestine, without any provision to retard its contents. In the ruminantia, on the contrary, the jaws are elongated, and admit of free lateral motion with flat grinding teeth, the stomach is complicated, and the intestine long and sacculated; in fact all things

conspire to ensure perfect comminution of the food, retardation of its passage, and a due absorption of its nutritious particles.

CHAPTER XII.

ABSORBENT SYSTEM.

Although Monro, Poli, Sheldon, and Carus, have described chyliferous vessels in many of the invertebrated classes, their existence in these animals has not yet been satisfactorily proved, and it is more than probable that their function is performed by the veins, the white blood of which resembles the chyliferous fluid of the vertebrata. The chyle varies much in its composition and properties in the various tribes of vertebrated animals, and even in the same animal according to the sort of food it lives on, being of a pinkish tint, with abundance of crassamentum in the different animals which subsist on nutritious animal food, while it is limpid and pale, with a great proportion of serum in the inferior animals. The chyliferous, like the other systems of the body, presents different grades of development in the different vertebrated classes. Thus, in fishes the vessels seem to consist of a single tunic, destitute of valves, and without conglobate glands; they form two strata of vessels between the coats of the intestine, and carry a limpid fluid to the receptaculum chyli, from which one or two thoracic ducts lead to the jugular veins or other branches of the cavæ. The lymphatics and lacteals communicate frequently with one another, and with the neighbouring veins, and when injected they present a beaded appearance owing to the presence of rudimentary valves.

The chyliferous system in the *amphibia* is the same as in fish, but in the *reptilia* it presents a higher degree of formation in the existence of valves, and the milkish appearance of the chyle, the place of glands is still supplied by the convoluted condition of the vessels as in fishes; here also, two or more thoracic ducts, frequently communicating, pass to the jugular or subclavian veins, or the angle between them, previously receiving the lymphatics from the head, neck, and arms. In the tortoise, the anastomoses of the thoracic ducts nearly conceal the trunk of the aorta. This system presents a somewhat higher grade of development in *birds*, both sets cf vessels being more numerous and distinct, the valves are more abundant, but yet admit of the passage of fluids from trunks to branches. Glands appear now for the first time, in connection with the lymphatics, but not with the lacteals. Two thoracic ducts, having but few anastomoses, terminate by several openings at the junction of the jugular and subclavian veins.

In the *mammalia* the absorbent system is better developed and

more distinct from the sanguiferous than in any of the preceding classes, as manifested in the sanguineous characters of the chyle, the elaborate structure of the vessels, the perfect condition of their valves, the increased number of conglobate glands, and the unity and distinctness of the thoracic duct. Sometimes this duct is double, as in the dog, and sometimes its branches open into the vena azygos, as in the hog. Occasionally its trunk divides, and having enclosed a narrow elongated space, called *insula Halleri*, the branches again unite. The mesenteric glands are of great magnitude in the cetacea, more detached in the pachydermata, and grouped into a mass, named *pancreas Asellii*, in the carnivora.

RECAPITULATION.

1. Lymphatics have been described, but not satisfactorily demonstrated, in the invertebrata.
2. No conglobate glands have been found in fishes; their absorbents are thin, convoluted, and furnished with rudimentary valves, and occasionally two thoracic ducts exist.
3. This system is the same in amphibia as in fishes, but in the reptilia the valves are more perfect.
4. In birds the absorbents are very numerous, the valves still more perfect, and glands for the first time met with.
5. In mammalia the entire system is marked by a higher type of formation: the thoracic duct is sometimes double as in the dog, and occasionally opens into the vena azygos as in the hog.

CHAPTER XIII.

SANGUIFEROUS SYSTEM IN THE INVERTEBRATA.

The systemic, or red-blood circulation was discovered in the higher animals by Harvey, in 1619; and by the researches of modern comparative anatomists, it has been found to have a much more extended existence; there is a considerable number, however, of the *cycloneurose* classes of animals, in which no distinct vascular system has as yet been detected. The first appearance of it which we observe in the lower animals, as in the earliest condition of the human embryo, consists of vessels alone, through which the fluids move in a circle, like the colourless blood in the cells of a plant. In the asterias, echinus, and holothuria among the *echinodermata*, a large vessel, in the form of a ring, surrounds the commencement of the alimentary canal, from which the systemic arteries are derived; the systemic veins send branches to the gills, from which the blood is returned by one large vessel to the heart.

Diplo-neura.—In the *earth-worm* two vessels, one above and the other below, extend the entire length of the body; they communicate by several cross branches, and join at their extremities, where small dilatations are observable, supposed to aid in propelling the blood, which moves in opposite directions. The large vessels of the annelida are endowed with a contractile power, and in insects, spiders, and the lower species of crustacea, large dilatations occur, capable of considerable contractility.

In the *leech*, hirudo vulgaris, the two principal vessels are placed on the sides, and lesser ones above and below, all anastomosing freely by transverse branches; of these the superior longitudinal and the inferior transverse only pulsate. It is the opinion of Müller that the lateral vessels alternately empty themselves from behind forwards; and others state that the blood is moved forwards in the upper vessel and backwards in the lower.

The arachnidans, which breathe by means of trachæ, seem to have a dorsal vessel only, without any ramifications. Those, on the contrary, which possess branchial lungs, have a well developed circulatory apparatus. The blood leaving the heart by the arteries is distributed to all parts of the body; having become venous it is returned to the pulmonary branchiæ by sinuses which supply the place of veins, and having undergone arterialisation, it is returned to the heart by the branchio-cardiac vessels, again to be propelled through the arteries.

In the higher *crustacea* the heart consists of two sinuses and a ventricle; from the latter, in the stomopoda, six vessels arise which distribute the blood to the eyes, liver, antennæ, &c. This fluid is next returned to venous sinuses in the neighbourhood of the branchiæ, through passages without any apparent parietes; the arterialised blood is brought from the branchiæ to the sinuses of the heart by vessels named *branchio-cardiacs*, from which it is received by the ventricle and sent into the arteries issuing from it, each of which is provided with a valve at its origin.

Cyclo-gangliata.—The greater number of the animals which compose this class are aquatic, and enjoy a branchial respiration. In the ascidiæ the heart is very simple, consisting merely of a thin membranous ventricle destitute of valves. The conchifera have two auricles and a ventricle; the gasteropoda and pteropoda possess a strong auricle and ventricle provided with valves. In the cephalopoda there is an aortic heart, and two branchial hearts, or dilatations; in these animals, the blood having been carried to the system by the arteries is returned by the veins to the branchial fringes; in some bivalves, however, a portion of it is sent direct to the heart without passing through the respiratory organ. In the gasteropodous and other mollusca the rectum passes through the ventricle.

CHAPTER XIV.

SANGUIFEROUS SYSTEM IN THE VERTEBRATA.

In the greater number of the invertebrate animals which we have hitherto examined, the heart and principal artery were placed above the alimentary canal and the chief part of the nervous system; but in the vertebrate classes the converse order obtains, the heart being below the alimentary tract; in the former division the blood generally arrives at the heart after having passed through the respiratory organ, while in the latter the blood flows from the heart to the respiratory organ. In the invertebrate classes, too, there is no vena porta, the liver being supplied by an hepatic artery alone.

PISCES.

The gills, which are the only respiratory organs of fishes, are placed in the course of the arterial circulation. The venous blood from all parts of the body is conducted to a single auricle which propels it into the ventricle, from which it is brought by the arterial bulb to the gills, where it is arterialised, and from which it is distributed by the branches of the aorta to all parts of the body. The caudal vein of the eel presents a contractile dilatation, to which Dr. Hall has applied the name of *caudal heart;* this doubtless assists in promoting the circulation in the caudal branches of the vena cava. Many look upon the heart of fishes and the artery issuing from it as analogous to the right heart and pulmonary artery of higher animals; but it is much more just to consider the heart as corresponding to the whole heart of the warm-blooded vertebrata, seeing that in some of the reptiles possessing gills, the blood is sent to these organs through the great systemic trunk. In fact, the heart, in these animals, acts at once the part of a pulmonary and a systemic heart in propelling the blood not only to the gills, but through all parts of the aortic system.

Portal-circulation.—The porta in fishes carries to the liver the venous blood from the stomach, intestines, spleen, pancreas, and occasionally from the genital organs, swimming bladder, and tail. In the gadus, however, as in reptiles, the venous blood from the tail and the central parts of the abdomen goes to the kidneys. In the silurus the blood from the posterior part of the body is distributed to the liver and kidneys: and in the carp, pike and perch, to these organs and to the vena cava. This vessel also receives the blood from the testicle, ovary, kidneys, and frequently from the swimming bladder.

AMPHIBIA.

The metamorphosis which this class of animals undergoes in passing from the pisciform to the reptilian state, is strikingly

illustrated in their circulatory system: beginning life with the single heart of a fish, and ending it with the double heart of a reptile. In the water salamanders the venous blood which has circulated through the body, is returned to a systemic auricle, and having passed through the ventricle, it is received by the bulbus arteriosus, and sent by the branchial arteries to the branchial leaflets. The pure blood is now received by the pulmonary veins, the confluence of which constitute, as in fishes, the descending aorta.

From this latter vessel a small branch passes off to the rudimentary lung, which is afterwards to become the pulmonary artery. As the animal changes from an aquatic to an atmospheric respiration, the branchiæ become absorbed, and the lungs proportionally developed. Their arteries experience corresponding changes, those of the former organs diminishing, while those of the latter increase with the growth of the lung. The two veins which return the blood from the rudimental lung also enlarge, and as they arrive at the heart, they undergo a remarkable dilatation, which constitutes the left auricle. Till lately the bi-auricular form of heart was supposed to be confined to the caducibranchiate amphibia, as frogs, toads, salamanders, and tritons, but the researches of Owen have proved its existence in the perennibranchiate amphibia also.

At the same time that the systemic auricle receives the impure blood from the cavæ, the pulmonic auricle receives the aërated blood from the lungs. From both of these cavities the blood is sent into, and mixed in, the single ventricle, from which it is sent by the one impulse to the lungs and to the system generally. From this description it is obvious that the blood is but partially purified, mixed blood being sent through the pulmonary arteries, as well as through the aorta and its ramifications.

REPTILIA.

In this class of animals we perceive a still higher grade of development than was met with in the amphibia; the ventricle is partially divided by a septum into two compartments, corresponding in most particulars to the two ventricles of warm-blooded animals. In some the septum is so imperfect as to be incapable of preventing the admixture of the blood derived from both auricles. In others, however, as the crocodile, the ventricles are separated completely, or communicate by a small orifice provided with a valve, which prevents the blood passing from one compartment to the other. In fact the heart in this singular animal is double, as in the higher vertebrata, so that the venous blood returned by the cavæ to the right auricle, passes from the right ventricle through the pulmonary artery to the lungs, while the pure blood returned from this organ to the left auricle is directed from the left ventricular compartment through the systemic arteries. The auriculo-ventricular orifices are provided with a muscular valve, and in the crocodile there are two.

It is curious, however, that in the whole of this class the descending aorta is formed by the union of two branches, the right branch arises from the left ventricular compartment, consequently carries pure, or nearly pure blood, which it distributes to the head, neck, chest, and upper extremities. The left branch, on the contrary, arises either from the right ventricular compartment, or what is tantamount to it, from the pulmonary artery. It is obvious, then, that the descending aorta carries a mixed quality of blood to the parts it supplies; but it is interesting to observe, that previous to the junction of the two aortic arches, the left gives off the cœliac axis which supplies the entire alimentary canal and digestive organs with venous blood. In the turtle, lizard, and some serpents, where the septum ventriculorum is imperfect, the pulmonary artery and aorta at once carry mixed blood, and in some of the chelonia, as the tortoise, the existence of ductus arteriosus ensures a more complete mixture of venous and arterial blood. The arteries arising from the ventricles are each provided wtth two valves.

Portal system.—In amphibia and reptiles, as in fishes, there are two lesser venous circulations; the one belongs to the liver, and the other, which does not exist in birds or mammals, belongs to the kidneys. In some reptiles all the venous blood from the posterior parts of the body is distributed to the liver and kidneys, while in others a portion is sent to the inferior cava; this latter vessel also receives the venous blood which has circulated through the kidneys.

AVES.

The heart, in this highly organised class of oviparous animals consists of four separate and distinct compartments, and indeed presents a more perfect typical form than is met with in even the mammalia. Its form is conical, being sometimes short and wide, as in the crane, and sometimes more elongated, as in the emeu. Its situation is mesial, its axis parallel to that of the trunk, and in consequence of the partial development of the diaphragm its apex rests between the lobes of the liver. The right auricle seems considerably larger than the left, and the auricular portion is distinctly divided from the sinus by two semilunar muscular valves; one attached along the anterior, and the other along the posterior side of the sinus. The venous blood is returned to the sinus of the auricle by an inferior and two superior venæ cavæ, and it is remarkable that the left superior cava receives the coronary vein just before its termination. The orifice of this vessel is opposite to that of the inferior cava, but separated from it by a semilunar membranous valve. The auriculo-ventricular opening is a small oblique slit, and reflux from the ventricle is prevented by a thick strong muscular valve so disposed as to give considerable impulse to the flow of blood through the pulmonary artery. There is a small muscular column at the upper part of the orifice, but it is only one

of the carneæ columnæ, of which few exist in the ventricle. In the left auricle a mere rudiment of valve is found between the sinus and the appendix. The parietes of the left ventricle are very thick, and the auriculo-ventricular opening is guarded by two membranous folds corresponding to the mitral valve in mammalia. The pulmonary artery and aorta are provided at their origins with three semilunar valves, those of the former vessel being thicker and stronger than those of the latter. The extremities of these valves will be found by careful dissection to be attached to cartilaginous or osseous points imbedded in the fibrous tunic of the vessels.

The pulmonary artery having arisen from the right ventricle at once divides into two branches, one for each lung; from these organs the blood is returned by two veins, which unite before they reach the left auricle. From the left ventricle arises the aorta, which immediately sends off two branches analogous to arteriæ innominatæ, for the supply of the head and wings. It may be observed that birds possess no palmar arches, nor, strictly speaking, a radial artery. The cerebral, orbital, temporal, and spermatic arteries are remarkable for their free and plexiform anastomoses. But of all the arterial plexuses, that of the organ of incubation requires special notice. It is formed by branches from the posterior thoracic, abdominal, cutaneous, and ischiadic arteries, immediately under the integuments of the abdomen. This plexus becomes enormously enlarged during the period of incubation.

The venous system in birds is remarkable for the frequency of its communications, especially one which exists between the united caudal, hemorrhoidal, and iliac veins and the vena porta, by means of which the blood from the viscera and posterior parts of the body may flow either into the cava or porta, a disposition obviously designed to guard against congestions: as yet it is a question concerning which contradictory opinions prevail, as to whether the branches of the pulmonary artery extend to the air-cells distributed over the body, or whether the blood in the systemic capillaries un-undergoes any change tending to its purification in the parietes of these cells.

MAMMALIA.

The form of the heart, and the distribution of the blood vessels in the whole of this class so closely resemble the human type, that it becomes necessary to notice only a few individual peculiarities; in the dugong and rytina for instance, among the cetacea, the heart is cloven by the deep separation of its two ventricles, and the orifice of the inferior cava is guarded by a fleshy Eustachian valve, which is wholly absent in the lion, the bear, and the dog. In the monotremata, the marsupiata, the porcupine, and the elephant, the right auricle receives one inferior and two superior cavæ as in birds, and the coronary vein terminates in the left superior cava. In the ourang-outang and the mole, only, is the apex of the heart inclined

to the left side as in the human subject. In the upper part of the substance of the left ventricle of the pig, the stag, and other bisulca, are two small flat bones, cruciformly disposed in the stag, they are formed about the third year of the animal's life, and are but slightly developed in the female. It has been generally supposed that the foramen ovale and ductus arteriosus remain permanently open in seals, otters, and cetaceans, and although the dissections of Cuvier, Home, Blumenbach, and T. Bell, go to prove that they have remained unclosed in a few instances, still we must look upon these as exceptions, admitting, however, that these passages continue longer pervious in these diving animals than in other mammalia.

As regards the arterial system some remarkable peculiarities are observed in the branches arising from the arch of the aorta, thus in the horse, the camel, and many of the long necked mammalia, this great trunk just after its origin divides into two branches, one becomes the descending aorta, the other ascends vertically and divides into a right innominata, a left subclavian and a left carotid, which latter appears in direction the continuation of the trunk. In the elephant there is but one coronary artery, and both carotids arise by a common trunk between the two subclavians.

The dolphin has an innominata on each side, this constitutes the type of the cheiroptera. In the marmot and the guinea-pig, the right innominata gives rise to the two carotids, and the right subclavian. This also is the type of the order quadrumana, and most of the carnivora. Among the peculiarities in the distribution of arteries we may notice the *rete mirabile* formed by the internal carotid at its entrance into the cranium in several carnivora and ruminant bisulca; the plexiform arrangement of arteries which exists under the pleuræ and between the ribs in the cetacea; and the remarkable anastomosing divisions of the arteries of the extremities and tail in the slow moving and climbing animals as the bradypus, myrmecophaga, pangolin, and stenops. This condition of the arterial system doubtless has reference to the peculiar living habits of the animal it exists in, thus in the cetaceans these serpentine vessels constitute so many reservoirs for containing arterial blood during the obstructions to the circulation which are almost inseparably connected with the aquatic habits of these mammalia, whilst in those with depending heads, the rete mirabile is admirably calculated to obviate the injurious effects of sudden influxes to the brain, and in the edentata the arterial divisions alluded to are no less indicated, lest the large trunks of the extremities should suffer from pressure during their long continued action in climbing.

The plexiform disposition, which characterises so many parts of the arterial system, is no less strikingly displayed in the venous. This is well seen in the tortuous sinuses which receive the intercostal veins in the porpoise, the vena azygos being absent in this animal. A beautiful distribution of veins constituting the *rete mirabile venosum*, is met with on the foot of the horse, where these

vessels run in innumerable parallel branches on the anterior surface of the coffin bone. Another peculiarity in this system is presented by the inferior cava, in the porpoise, the seal, the common and the sea otter, consisting in a considerable dilatation of this vessel between the liver and the diaphragm, similar to what is observed in tortoises and diving birds.

A general review of the vascular system indicates that the heart in its simplest form resembles a vessel endowed with contractility, as exemplified by the vessel-like multiple hearts which constitute the vascular trunks of the annelides, the contractile trunks on the alimentary canal of the holothuria, the dorsal vessel of insects, &c. In the embryo of the highest warm-blooded animals the heart is at first tubular, and it is interesting to observe, that during the progress of its development it passes through, and resembles the several forms which constitute its permanent type in the adult state of fishes and reptiles, even the clefts in the neck, with the arched divisions of the aortic trunk, which are persistent in reptiles, may be seen in the human embryo at a very early stage of its development, and the ductus arteriosus, which is single in mammalia, but double in birds, is the last of those arches which remains unclosed in the fœtus. These arches may be well seen by inspecting the embryo of a bird on the third day of incubation.

The frequency of the heart's action varies much in different animals, and even in the human subject, from a variety of causes.

In a fish it beats in a minute from	20 to 24
In the frog, about - -	60
In birds, from - -	100—140
In the bat, - -	200
In rabbits, - -	120
In the cat, - -	110
In the dog, - -	95
In the sheep, - -	75
And the horse, - -	40
In the human embryo, -	150
At birth, - -	130 to 140
During the first year - -	115—130
During the second year -	100—115
During the third year, -	90—100
During the seventh year, -	85— 90
About the fourteenth year -	80— 85
In the middle period of life, -	70— 75
In old age, - -	50— 65

RECAPITULATION.

1. The systemic circulation was discovered by Harvey in 1619.
2. In the higher radiata a large artery surrounds the beginning of the alimentary canal, in the form of a ring, from which the systemic branches arise.

3. A distinct heart is first seen in the crustacea.

4. In the gasteropodous mollusca, as the snail, the rectum passes through the heart.

5. There is no portal circulation in the avertebrata.

6. The heart of a fish consists of a single auricle and ventricle, and the blood of the porta is distributed to the liver and kidneys.

7. All the amphibia have at first the single heart of a fish, but the caducibranchiate species terminate life with the double heart of a reptile.

8. The heart of birds consists of four distinct compartments, as in mammalia, but rather more perfect, owing to the existence of its fleshy valves.

9. The heart of the higher warm-blooded mammalia, even that of man, in the course of its development, represents the several grades which constitute the permanent types of the lower animals.

CHAPTER XV.

RESPIRATORY SYSTEM IN THE INVERTEBRATA.

The respiratory organs are sometimes placed in the interior of the body in the form of lungs sometimes towards its exterior in the form of lamellated, ramified, pectinated, tufted, ciliated, or pinnated processes, termed gills, or branchiæ, and a third form of respiratory apparatus is obtained by the development of a system of tracheal tubes, ramified to an exquisite degree of minuteness, and widely spread through all the organs of the body. Animals provided with lungs generally breathe atmospheric air, whilst in those furnished with branchiæ respiration is accomplished by means of water. An exception to the former, however, is met with in the holothuria; and to the latter, in the terrestial crustacea. It will appear in the progress of this article that some of the vertebrated animals commence life by a branchial respiratory and terminate it by a pulmonary, and that others enjoy a mixed form of respiratory organ all through. In fact, nature seems almost to have exhausted her ingenuity in the construction and development of respiratory apparatus.

Cyclo-neura.—In the lowest classes of this division the only respiratory organs detectible are small cilia pervading the entire surface, but so minute as to require high magnifying powers to render them visible. The tentacula and the whole surface of the body are subservient to the function of respiration in the polypifera. In the asterias and sea-urchin among the echinodermata, the water passes into and out of the cavity lined by peritoneum, in which the viscera are lodged. In the holothuria the water is alternately re-

ceived and emitted from a tube which is ramified in an arborescent manner, with terminal cellules.

Diplo-neura.—The highly vascular skin of the *entozoa* performs the function of respiration—in some, through the medium of water; and in others the blood is oxygenated on the mucous surface of the animals they infest. In the *cirrhopoda* respiration is performed by the arms and by the leaf-like fringed membranes attached to the anterior part of the sides of the body. The surface of the body is in general the seat of respiration among the *annelida*, but in the lumbrici, nereides, and hirudines respiration is in part effected by a series of minute membranous sacs under the skin of the abdomen, each having a separate external opening. Respiration is aërial in the greater number of *insects*, the air being received through a number of stigmata, and carried by the tracheæ in some cases into vesicles, and in others into longitudinally ramifying trunks.

Many insects in their larval state breathe by means of branchiæ in the water, and some in their perfect condition breathe water, although they have an internal tracheal apparatus; from the water in these branchiæ the air is separated, and passed in the gaseous state through the ramified tracheæ. There is a very curious fact connected with the *eristalis*, this disgusting insect has the last ring of its body elongated into a membranous tube, within which there is a second horny tube, which the animal can extend to the surface for the purpose of respiration, whilst it lives at the bottom where it procures its food in the filth of sloughs, sewers, and stinking privies. The tracheary *arachnida* resemble insects in their tracheal tubular respiration, whilst the respiratory organs of the pulmonary arachnida consist of small sacs opening externally, and situated at the under surface of the abdomen. Both sets of organs are enjoyed by the segestria and dysdera. In tracing the progress of development of the respiratory apparatus in the higher *crustacea*, as the astacus fluviatilis, it will be found to present four principal periods; 1stly, that which precedes the appearance of this apparatus; 2dly, that in which the branchiæ are not distinguishable from the organs dedicated to locomotion or mastication; 3dly, that characterised by the transformation of these into organs wholly dedicated to respiration, and distinct from the extremities; and 4thly, that during which the branchiæ sink inwards, and become lodged in the branchial cavities.

By reviewing the respiratory apparatus in the different groups of crustaceans, it will be found that the several stages of development of the higher orders constitute the permanent types of the lower series; thus, to the first stage of organisation belong the greater number of the entomostraca and copepoda; to the second, the branchiopoda; to the third, the amphipoda; and to the fourth the entire order of the decapoda. The greater number of the crustacea live under water; some, however, as the gecarcini, or land-crabs, constantly live out of water, but it is necessary that their respiratory membrane shall be kept humid, and for this purpose the membrane is thrown into folds in the form of reservoirs for containing water.

Cyclo-gangliata.—The greater number of this division breathe in water, by means of gills, some however, breathe by lungs in the air. The first mode of respiration is enjoyed by the tunicata, conchifera, pteropoda, cephalopoda, and some of the gasteropoda, the remainder of this class breathe atmospheric air, by means of a lung in the form of a large cavity, placed beneath the mantle. A curious circumstance connected with the conchifera is, that the eggs on escaping from the ovary, are deposited between two layers of the branchial membrane, where they increase in size and undergo incubation.

CHAPTER XVI.

ORGANS OF RESPIRATION IN THE VERTEBRATA.

PISCES.

This entire class is covered with branchiæ, by means of which they abstract the free oxygen contained in the water. In the sharks and rays, and in all the osseous fishes there are four gills on each side, supported by as many branchial arches of cartilage or bone, connected to the os hyoides.

Each gill consists of a double series of lance-shaped lammellæ closed in by a movable cover, *operculum.* Generally there is but a single opening for the passage of the water, but in some instances, especially among the cartilaginous fishes, there are several. In consequence of the swimming bladder of fish being supposed by Carus, Blumenbach, and many others, to be subservient to the purposes of respiration, it merits some notice in this place.

This organ, which is sometimes divided by a septum, as in the genus cyprinus, and sometimes absent, as in the pleuronectes, lophius, and mackerel, is placed in the abdomen, close to the spine, and below the kidney; consists of an internal vascular lining membrane, a strong fibrous tunic, and a partial investment of peritoneum. In fresh-water fishes, it has been found to contain nitrogen, and in salt water fishes, chiefly carbonic acid gas. From its anterior part a canal, *ductus pneumaticus*, passes forwards and opens into the œsophagus, except in the sturgeon where it opens into the stomach. This duct is double in the cod, in the carp it possesses valves so disposed as to admit of the egress, but prevent the ingress of air; it is absent in the sciura, cobitis, burbot, and others. When we consider that this organ is largest in such fishes as swim with greatest velocity, and wanting in those where large fins or a powerful tail compensate for its absence, we are disposed to agree with those who regard it as an organ of progressive motion.

AMPHIBIA.

Frogs and salamanders in their tadpole state, breathe by gills, which during the earliest periods of their existence are placed externally; they also possess rudimentary lungs, which become developed as the animals change from the aquatic to the aërial respiration. The perennibranchiate amphibia, as the proteus, siren, and axolotl also possess both sets of organs, and retain them through life, but here the lungs always present the rudimentary type, and it is even doubted whether they subserve at all to the function of respiration. In these as well as in the larval condition of the caducibranchiate genera, the pulmonary organ is in the form of a mere sac, and it is only during the metamorphosis that it assumes the cellular character. In the adult state of all the higher orders of amphibia respiration is accomplished in a manner different from all other air-breathing animals, viz., the mouth being fully distended by the air which enters through the nostrils, these passages together with the pharyngo-œsophageal are closed, the mouth then suddenly contracts by the action of the surrounding muscles, and the air is forced by an effort of deglutition through the glottis and trachea into the lungs. Hence, one of the most effectual ways of killing a frog is to keep its mouth open for a short period; this mode of inspiration is accounted for by recollecting that the ribs are absent in these animals.

REPTILIA.

In most of the amphibia the trachea is very short and perfectly membranous. In this class it is somewhat longer, and cartilaginous plates begin to appear in it; these plates which are first seen in the dactylethra, do not form perfect rings, but present the appearance of perforated lamellæ irregularly disposed. In the bronchi of the cæciliæ, however, the cartilaginous rings are much more complete. In lizards and serpents the lung is a mere cavity with cellular parietes, having perforations which communicate with the neighbouring cells. Turtles have a more complicated structure, approaching that of warm-blooded animals.

AVES.

The lungs, in this class, are confined to the back parts of the cavities of the thorax and abdomen by the serous membrane common to these cavities; they are of a flattened, elongated form, smooth anteriorly, and grooved posteriorly by the ribs, between which they are impacted; they are of a bright red colour, and of a loose spongy texture; on the surface of the lungs there are openings through which air passes from the bronchial tubes into large neighbouring cells. In birds not organised for flight these cells, are confined to

the abdomen, but in others they extend along the neck, and even into the extremities: they also penetrate the cavities and diploë of the bones, a discovery for which we are indebted to Mr. Hunter. This great physiologist injected the medullary cavities of the bones from the trachea: he also tied this tube, and having broken the humerus of a fowl, and the femur of a hawk, he found that the birds respired for a short time through the artificial openings. The proportion in which the osseous system of birds is permeated by air has reference to their respective modes of progression, thus almost every bone in the body admits air in the kite, the hawk, the eagle, and other birds of high flight; and in the hornbill even the phalanges of the toes contain air. Four uses have been ascribed to this extension of the respiratory system in birds—first, to subserve the function of respiration; secondly, to aid by mechanical pressure the action of the lungs; thirdly, to render the body specifically lighter for the purposes of flight; and fourthly, by the distension of the cells in the extremities to assist in maintaining the wings in a state of extension, during long-continued flight. Mr. Hunter supposed it contributed to sustain the song of birds and to give it strength and tone.

The *air passages* in birds consist of a superior larynx, a trachea, and inferior larynx, and two bronchi with their ramifications. The superior larynx is situated behind the root of the tongue, resting on the uro-hyal element of the os hyoides; it is composed of from four to ten bony or cartilaginous pieces, and two pairs of muscles; thyro-arytenoidea and constrictores glottidis. The trachea is composed of a series of bony or cartilaginous rings, which form complete circles, with the exception of the two first; they are closely approximated, and sometimes overlap. Many birds, as the rasores, have no inferior larynx; in others it presents different degrees of development, thus, in the genus falco there is but one pair of muscles; in the parrot tribe three, and in the insessores, where this organ attains its greatest degree of perfection, five. The rings of the bronchi do not form complete circles, but gradually become smaller, and finally disappear.

MAMMALIA.

In the entire of this class there is great similarity in the respiratory organs, not only to each other but to the human type of formation. An epiglottis exists in all, and is divided at its superior extremity in the seal, the hare, and the ant-eater. The larynx in all the mammalia consists of the same parts generally as in man, but occasionally modified in obedience to particular circumstances. Thus, in the cetacea this organ ascends as far as the posterior nares, and communicates with the spouting hole, which opens at the top of the head by a single or double orifice, closed by a fleshy valve in the form of two semicircles. The great size of the larynx in the lion accounts for the powerful and terrific roar of that ani-

mal. The peculiar grunting voice of the pig is produced by large lateral cavities communicating with the small ventricles of the larynx, and the neighing of the horse results from the vibrations of membranous folds connected with the chordæ volcales.

The trachea varies considerably in the length, breadth, and number of its rings; thus, in the seal, the porpoise, the cheiroptera, and several rodentia, its rings form complete circles as in birds; their number varies from 14, presented by the mouse, to 78, as seen in the seal. In the sloth the trachea descends considerably in the chest, and again ascends to divide into the bronchi. The lungs present very few varietes in the class mammalia. In the cetacea they are remarkable for their elongated, flattened form, and for the free communication of their cells with each other.

RECAPITULATION.

1. The respiratory apparatus is very extensive and greatly varied in the invertebrata, in the lowest orders of which it is usually confined to the surface of the body.
2. Respiration is performed by gills in fishes, and in the caducibranchiate amphibia, during the tadpole state; in the siren and proteus it is in all probability performed all through life both by gills and lungs.
3. In birds this system is extended into the bones and into the large cells of the thorax and abdomen.
4. The organs of respiration throughout the class mammalia. are very similar to those of man.

CHAPTER XVII.

ORGANS OF GENERATION IN THE INVERTEBRATA.

Notwithstanding the varied modifications observed in the organs of generation throughout the animal kingdom, the reproductive function will be found to conform to a few leading types, as the *fissiparous*, *gemmiparous*, *oviparous*, *viviparous*, and *ovo-viviparous*. *Fissiparous* generation consists in the division of an animal into two or more, similar in every respect to the original being. In this form of generation, which is met with in some of the infusoria, cestoidea, and annelida, the line of separation takes different directions, being transverse in the paramœcuim, and vertical in the vorticellæ. In *gemmiparous* generation the young appear as sprouts from the body of the parent: it is more extended than the last, being met with in the polypine and coralline animals, in sponges, cystiform entozoa, and in some acalephæ. These two forms of

reproduction appertain to animals unprovided with special organs of generation.

In *oviparous* generation, which belongs to birds, many reptiles and fishes, the egg, after fecundation, passes through the oviduct from the body of the parent, to be hatched by the influence of external agents. Most mammalia afford examples of the *viviparous* form of generation, here the ovum remains within the uterus of of the female until it is capable of independent life. Many animals, however, besides mammalia, bear their young alive, examples of which are to be met with among the reptiles, fishes, mulluscous and articulate animals. The last form of generation above alluded to is the *ovo-viviparous*, which implies the production of living fœtus, the ovum being hatched within the body of the parent; but never contracting a vascular connection with the uterus, this is the case with the monotremata, as the echidna, and ornithorhynchus, and also with the monotrematous marsupiata, as the opossum, and kangaroo.

All the higher classes of animals possess generative organs of two kinds, the co-operation of which, for the purposes of reproduction, constitutes the distinction of sex, into male and female.

The following table exhibits a view of the reproductive process in the different classes of animals, as given by Dr. Thomson, of Edinburgh, in his matchless article on generation, in the "Cyclopædia of Anatomy and Physiology."

Reproduction.	Non-sexual	Fissiparous . .	Parent splits, each part a new animal. 1. Transverse. 2. Longitudinal. 3. Irregular. Parent splits and discharges the young.
		Gemmiparous .	Budding upon the parent stock. Separated buds, gemmæ, or sporules. 1. On all parts of the body. 2. On one part or organ only.
	Sexual .	Hermaphrodite	Both sexual organs on one individual. 1. Self-impregnation. 2. Mutual impregnation.
		Diœcious . .	Oviparous laying eggs which are hatched. 1. External fecundation. 2. Internal fecundation. Ovo-viviparous, eggs hatched within the maternal body. Mammiferous, suckling the young. 1. Monotrematous. 2. Marsupial. 3. Placental or strictly viviparous.

From the above table, it appears that there are a vast number of animals wholly destitute of generative apparatus, and where organs first appear, the animals seem to have the power of propagating by means of ova, without copulation; in many of the lower animals,

however, as the annelida, the acephalous, and gasteropodous mollusca, both sets of organs are placed on the same individual, constituting it an *hermaphrodite*. Some of animals of this class, as the holothuriæ, possess the power of self-impregnation, whilst others, though possessing double organs, require mutual impregnation; this is the case with the leech, and the common earth-worm. In all the *insect* tribes the sexes are separate, the male organs being the testicles, the vesiculæ seminales, the excretory tubes, and in many, the prehensores or organs for seizing the female during coitus. The female organs consist of the ovaria, the oviducts, the spermotheca, or receptacle for the male semen, and the ovipositor, an instrument for directing the ova to their proper location at the period of extrusion.

The generative system of the *arachnida* and *crustacea* is very simple, consisting in the male, of testes and vasa deferentia, and in the female, of membranous ovaries with their excretory ducts. These organs are double in each sex, and quite distinct from each other.

In the *mollusca*, the generative organs present some peculiarities; there is but one testicle in the male, and one ovary in the female, each placed on the right side of the neck. The penis is of huge dimensions in the gasteropoda, while in the cephalopoda it is quite rudimentary; but, by way of compensation, the vas deferens is large, convoluted, and *muscular*.

When two snails amorously disposed, meet, as Professor Jones, of London, lucidly observes, they begin their blandishments by rubbing the surfaces of their bodies together; after some hours the generative orifice on the side of the neck is seen to dilate, and to display within its cavity three apertures, one from the penis, another from the female organs, and the third from the sac which contains a calcareous quadrangular spike, called the dart; the use of which seems to be to excite to love its sluggish, sleepy, apathetic associate, by pricking the surface of its body; at length his dart is broken, and he becomes in turn the object of a similar attack; both the reptile cupids having thus exhausted their quivers, and received, each, the love inspiring wound, the other two orifices now dilate, from one the long whip-like penis protrudes, and is received by the vaginal orifice of the other; these phenomena being reciprocal, they mutually embrace and impregnate each other.

CHAPTER XVIII.

ORGANS OF GENERATION IN THE VERTEBRATA.

PISCES.

In this extensive class, the generative apparatus is comparatively simple, consisting in the female osseous family of two large membranous ovaries, with short oviducts, opening in the vicinity of the anus. The ova are generally very numerous, and are deposited in shallow water where they receive the fecundating influence of the male, and the genial heat of the solar rays. In the males the testicles are of great size and composed of a congeries of convoluted tubes; the semen is discharged by the vasa deferentia, and diffused through the water in the neighbourhood of the ova, which are thus impregnated. The presence of a penis in this class is not necessary, seeing that copulation does not occur; to this, however, there are a few exceptions, in which the ova are fecundated prior to their discharge; and in the blennius viviparus, the young are produced alive, being hatched within the oviduct. In these rare instances, the vas deferens protrudes externally in the form of a little penis. In the eel, the lamprey, and many cartilaginous fishes, the ova are suspended in the interior of the abdomen where they receive the influence of the semen, and are discharged by a simple orifice near the anus.

AMPHIBIA.

The ovaria of these animals are smaller, but in other respects similar to those of the lamprey; the oviducts are long and tortuous; they commence by a fimbriated extremity, and previous to their termination in the cloaca they enlarge to retain the ova for some time before expulson. In the frog, the testicles, which are two in number, are placed on the kidneys, and their excretory tubes discharge themselves into the ureters. In the majority of instances, the ova are fecundated in exitu by the sprinkling of the semen from the male which is placed on the back of his mate. In the triton, and a few others, the semen diffused through the water passes into the genital organs and produces internal impregnation. The salamander alone possesses a rudimentary penis, and in this case, too, the eggs are hatched within the oviduct.

The *reptilia*, for the greater part, possess a generative system, the same as the amphibia; the higher orders accomplish internal impregnation. The males of serpents are generally provided with two penises which, instead of being perforate, are grooved for the passage of the semen into the cloaca of the female. In the sauria the penis is bifid, and its extremities covered with recurved spines.

AVES.

In the males of this class, the testes, two in number, are placed high in the abdomen, beneath the kidneys; they are subject to remarkable variation of size, according to the period of the year their office is required; thus, in January the testicle of the sparrow is about this size, o, and by April it attains the size of a large pea. The vasa deferentia, seldom much curved, pass down and terminate separately on a rudimentary penis in the urethro-sexual pouch. The epididymis is quite rudimentary, and varies much in colour, being black, yellow, or green. Coitus is usually effected simply by an eversion of the cloacæ, therefore the intromittent organ is only rudimentary: in those birds, however, which copulate in water, as the drake, swan, &c., it necessarily attains a larger size. It is sometimes double as in serpents, and is always grooved along its upper surface, for the passage of the semen. The ovarium and oviduct are confined to the left side, they primarily, however, exist on both sides, but rarely continue their development on the right. A clitoris is present in the females of those species whose males are provided with a penis.

MAMMALIA.

The male organs of generation in this class consist of the testicles, vasa deferentia, penis, urethra, vesiculæ seminales, the prostatic and Cowper's glands, and with one interesting exception, supplied by the monotremata, the genito-urinary systems are quite distinct from the digestive. In by far the greater number of mammalia the *testicles* descend into the scrotum as in man; in some, however, as the amphibious mammalia, the cetacea, the elephant, and the ornithorhynchus, they never leave the abdomen, and in others, as the bat, the mole, and the hedge-hog, among the insectivora; the rat, the guinea-pig, the porcupine, and the squirrel, among the rodentia, they descend during the rutting season, and return into the abdomen after it is over. The communication between the tunica vaginalis and the peritoneum remains unclosed in those animals in which the testicles descend, except man, and where these glands occasionally pass into and out of the cavity, the communication is very free. The *vasa deferentia* are very serpentine in those animals where the testicles remain in the abdomen, and in ruminants, the elephant, and especially the horse, they are greatly dilated near their termination in the urethra.

Vesiculæ Seminales.—There seems to be no general law for the presence or absence of these accessory bodies. They are met with in the camel, elephant, bull, ram, horse, boar, guinea-pig, rabbit, hedge-hog, &c. In these animals they have either no communication, or a very imperfect one, with the vas deferens. In man and the simiæ only is the communication free and direct. The *prostate*

is more constant in its existence than the vesiculæ, being found in all orders of the mammalia, excepting perhaps the greater number of the rodentia and insectivora. It is double in the elephant, the camel, the horse, and some others. *Cowper's glands,* which are small, and situate behind the bulb of the urethra in the human subject, are large, and often increased in number in other animals; thus in the opossum and kangaroo-rat there are four, and in the wombat, kangaroo, and others, as many as six. They are absent from the greater number of carnivora, ruminantia, and cetacea. In the marsupiata they are covered by a strong muscular stratum, and in the icheneumon, their ducts run forward, and open near the extremity of the penis.

Penis.—This organ is modified considerably throughout the class. Thus, in the digitigrade carnivora, as the dog and the lion, its two crura are separated by a distinct fibrous septum, which is absent in the cetacea, pachydermata, and plantigrade carnivora. In the cheiroptera, quadrumana, cetacea, rodentia, and carnivora, with the exception of the hyena, and a few others, the penis is occupied by a cylindrical bone occasionally grooved. Remarkable peculiarities exist in the intromittent organ of the marsupiata; in the opossum the glans is bifid, and has three openings, one for the urine, and two for the semen. In the ornithorhynchus paradoxus the penis is double anteriorly, and in the hystrix, it divides into four glands, each furnished with sharp papillæ perforated for the discharge of the semen, but in neither of these strangely organised animals does the urine pass through it, this organ being concealed within the cloaca. The urethra shall be deferred till the consideration of the urinary organs.

The *female* organs of generation in the mammalia consist of the vulva, clitoris, nymphæ, vagina, uterus, Fallopian tubes, and *ovaries.* These latter organs are invariably double; in the marsupiata their structure is racemose as in birds, but in all the other genera they are more solid, and approach more or less the human type. The *Fallopian tubes* present but few peculiarities, except in the echidna and ornithorhynchi, where they experience a dilatation inferiorly to supply the place of a *uterus*, and afterwards open separately into the short vagina, on each side of the orifice of the urinary bladder. In the lower orders of mammalia the urethral and sexual passages are blended together, the *uterus* is elongated in form, and thin in its walls; in the carnivora, ruminantia, pachydermata, and cetacea, a mesial cleft appears, and the cornua are greatly developed; and in the marsupiata and most rodentia, the organ is divided into two lateral halves, each opening separately into the *vagina*, which, in the virgin state of the sloth, the ass, the mare, the pig, and the cow, is divided by a narrow vertical septum. The external organs of generation afford no striking peculiarities, except in the deficiency of nymphæ and hymen.

From a review of the above details of the generative organs in the marsupial and monotrematous orders, one must expect to find

some peculiarity in their mode of generation. In all the other mammalia the ovum is fecundated in the ovary, from which it descends through the Fallopian tube to the uterus, in the higher orders about the *twelfth* day. An intimate vascular connection is now established between the ovum and the uterus, by means of the placenta, and continues till the embryo is fully formed, and as we say, capable of enjoying an independent existence. This constitutes the period of utero-gestation, which, in the human subject is ten lunar months, but varies in almost every species of the class. A very different process, however, takes place in the animals above alluded to, thus in the kangaroo, the fœtus, small and imperfect, leaves the uterus about the thirty-ninth day after conception, and is lodged by the mother in the marsupium or pouch formed for its reception on the lower part of the abdomen, by a fold of integument in which the mammary gland is placed. Shortly after it reaches the pouch, it is found attached by its mouth to one of the nipples, from which it receives a constant supply of milk; this is rendered more secure by the gland being covered over by a stratum of muscular fibres, which enables the mother to feed the fœtus at pleasure.

The mode of breeding of the *monotremata* is as yet involved in some obscurity. The word monotremata means animals with a single outlet from the genito-urinary and digestive organs, called a cloaca; and is applicable to all the marsupiata, but is at present confined to the edentate species of them, as the echidna and ornithorhynchi. Previous to the late valuable researches of Mr. Owen, the existence of mammary glands in these animals was denied, which, combined with the structure of their ovaries, and their peculiar development of uterus, led to the supposition of their being oviparous in their generation.

Although the structure of their generative organs, the presence of mammary glands, their bearing their young alive, and suckling them, confer on them the ovo-viviparous type of generation, it must be acknowledged they possess many characters in common with reptiles.

RECAPITULATION.

1. All forms of generation conform to the fissiparous, gemmiparous, oviparous, viviparous, and ovo-viviparous.

2. These organs are separate and distinct in the insecta, the annelida, and the crustacea. In the mollusca they are single, and confined to one side.

3. This system is simple in fishes, and a rudimentary penis occasionally present.

4. Internal impregnation rarely occurs among the amphibia or reptiles.

5. In *birds* the size of the testicles varies according to the season, and the penis is often absent.

6. In some orders of *mammalia* the testicles never leave the abdomen, and in others they descend at certain periods.

7. There is no general law for the presence or absence of vesiculæ seminales or prostate, the latter is more generally present.

8. The penis in many instances is furnished with a bone; in some it is bifid, and in the ornithorhynchus no urine passes through it.

9. The generative organs and mode of generation are peculiar in the monotremata.

CHAPTER XIX.

URINARY ORGANS IN THE INVERTEBRATA.

The urinary, like the biliary and lachrymal apparatus, consists of four principal parts, each having its peculiar office consigned to it, and all jointly contributing to the same end—namely, the separation from the blood, and the discharge from the system, of certain decomposed and effete animal and saline matters. The urinary organs, when complete, as they are in the higher orders of animals consist of the kidneys, the ureters, the bladder, and the urethra.

Although the mollusca secrete urine, and uric acid has been detected in the long convoluted cœca of insects, and even through the bodies of cantharides; yet no perfect urinary system has been discovered in the great invertebrate division of animals. It is more than probable that the function of the kidneys in the majority of instances devolves on the respiratory, the cutaneous, and the biliary systems, together with certain glands, many of which serve not only for the elimination of noxious materials from the system, but as organs of defence on the approach of danger; in this latter light may be regarded the acrid secretions of bees, beetles, wasps, and spiders; as also the ink of the cuttle-fish which has the effect of blackening a considerable extent of the surrounding water, and thus baffling the attacks of its enemies: and among the vertebrata, a striking example is presented by the *yagouaré* of Azara, one of the mephitic weasels of Chili, whose urine is rendered so intensely offensive by the secretion of some adjoining glands, that dogs or other animals which have been sprinkled with it during their pursuit of this creature, are said to have torn portions of their own skins off from disgust, notwithstanding careful and repeated ablutions.

CHAPTER XX.

URINARY ORGANS IN THE VERTEBRATA.

PISCES.

The *kidneys* in this class are long and narrow, sometimes extending the whole length of the abdomen, as in the burbot. They generally present the appearance of forming but a single mass, their separation being only indicated by the presence of the ureters and the cava. The *ureters*, which arise by numerous fine radicles, soon unite in all the osseous fishes, into a single tube, which forms a heart shaped dilatation previous to its termination behind the anus, in common with the sexual organs.

Bladder.—This reservoir is absent from all the osseous, and several of the cartilaginous fishes, as the ray and shark, in which the ureters open as in birds, into a cloaca: when it is present as in the lump-fish, it receives the ureters anteriorly, and opens behind the anus in common with the vasa deferentia.

AMPHIBIA.

The kidneys are more distinct in this class than in fish. They are greatly lengthened in the aquatic genera, but are much shorter in the frog. The ureters convey the urine to the *bladder*, which is situated in front of the rectum: in the frog it is of considerable size, its walls are thin, and its fundus presents two cornua. In the *reptilia* the kidneys afford but few peculiarities, being elongated in the lizard, as in fish, and somewhat oval in the tortoise. The ureters are longer in this class than in the amphibia, and discharge themselves either into the cloaca or *bladder*. This organ is absent from the ophidia, and several of the sauria, as the lizard, and the crocodile. It is very large in the chelonia, as the tortoise, and it is singular, that the ureters instead of going to it, empty themselves into the urethra in front of it, so that the urine has to re-ascend to the urinary reservoir.

AVES.

In this extensive oviparous class the *kidneys* are of great length, extending along the spine, from the lungs to the lower end of the rectum. These organs are relatively larger in birds than in the terrestrial mammalia—a circumstance which is explained by recollecting the nature of their integuments, and the little transposition they admit of. They are of small size in the bustard and heron, and their lower extremities are somewhat blended together in the coot. Their structure is remarkable for the absence of cortical portion; the tubuli uriniferi run to the surface, and by their con-

fluence form the commencement of the *ureter*, which descends along the surface of the kidney, and posterior wall of the rectum, and terminates in that part of the cloaca called the urethro-sexual cavity. The space between their termination and that of the rectum is large in the owl and many aquatic birds, and is looked upon by some as a rudiment of urinary bladder.

The *supra-renal capsules* are small, of a bright yellow colour, and placed on the inner and upper part of each kidney, in contact with the testicle or the ovary. They are erroneously supposed by some to have some functional relation to the generative system.

MAMMALIA.

The *kidneys* are lobulated in the cetacea, seals, otters, bears, the elephant, the ox, &c., as in the human fœtus. In the otter each kidney consists of about ten lobules; in the bear of about fifty, and in the seal as many as a hundred and thirty. They present a lobulated appearance in many other mammalia during the early periods of existence. The *ureters* enter the bladder in an oblique direction, a little behind its neck, in all the animals of this class, with the exception of the echidna and ornithorhynchus, in which they open into the urethra near its commencement, so that the urine must re-ascend to the bladder, as in the chelonian reptiles. In the mammalia generally the *bladder* lies more loose in the abdomen than in the human subject, owing to its more perfect peritoneal investment. For the greater part it is more muscular and less capacious in the carnivora than in the herbivorous tribes. In the rodentia, however, it is small and fleshy. The shape of the bladder will be found to vary in obedience to age, sex, and species, the younger the animal, however, the more elongated will it be found, and in the human embryo it is cylindrical, tapering towards the urachus above, and the urethra below.

The *renal capsules*, like the kidneys, are lobulated in the cetacea, and other aquatic mammalia, and are found relatively very large in the young of animals possessing them. The *urethra*, as in the human subject, consists of a membranous or muscular, and of a spongy portion, the former receiving the accessory secretions. In the boar and many ruminants these two portions join at an angle. The corpus spongiosum arises by two roots in most of the marsupiata, and in the kangaroo, the urethra runs through the centre of the penis to its extremity.

RECAPITULATION.

1. In the great invertebrate division of animals, the functions of the kidneys seem to be performed by other parts, as the surface of the body generally, and certain glands.

2. Kidneys exist in all fishes, but a urinary bladder is confined to the cartilaginous tribes.

3. Birds have kidneys and supra-renal bodies, but no bladder.

4. The kidneys are lobulated in the adult state of many, and in the fœtal state of most mammalia.

5. The ureters open into the bladder in all the mammalia, excepting the monotremata.

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